

Systematizing Randomness: A new decorative order.

By Johnnie A Arnold

(Arthur)
Submitted in the fulfilment of the requirements for the degree of Master of Fine Art (Research)

Signed statement of originality

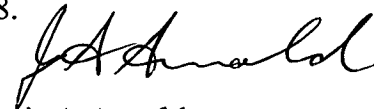
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ABSTRACT:

This project has investigated the strategic development and design of decorative systems that can operate as independent entities or be part of an adaptive system of architectural ornament. It is not about autonomous art objects. The project presents a re-invention of process, methodology and a new strategic capability for the generation and development of systems for a new decorative order.

A primary focus in the research has been the development of complex construction line drawings that form the structural web on which aperiodic and interlaced patterns are structured. Central to this project thesis has been the expansion from gallery wall mounted constructions and drawings to a number of systems of decorative, volumetric, sculptural configurations for integration and adoption into architectural surface or façade.

The original drawings remain in the gallery but the resultant spatial units or modules are installed on buildings as required. Considerable in-depth analysis of wooden door, window lattice and ceiling ornament systems in the Alhambra was undertaken within the project. Islamic interlaced ornament consists of geometrically complex/inter-woven lathes of inlaid wood integral within the fabric of building construction where line/structure are one.

The move to computer aided drafting (CAD) has facilitated the development of new spatial units, modules and systems. The unexpected impact on drawing has been a vastly increased capability to explore and produce more complex constructions than was previously possible using hand drawing techniques. These new decorative systems provide a grammar of applied ornament, which are both fragmentary and coherent. The resulting works have an exciting ‘un-predictability’.

CHAPTER ONE: CENTRAL ARGUMENT

This project is about the systematic generation of methods: of developing geometrical design tools and unique methodologies that can be adapted to aid in the design processes and the production of new forms of decorative systems. My method of research has been a strategy of extraction and detective work – finding out methods of geometric construction and applying these older fundamental principles to contemporary CAD techniques. It is a strategic system of geometric derivation and of manipulation using principals that are related to a preceding historical trade/craft based, architecturally applied, surface

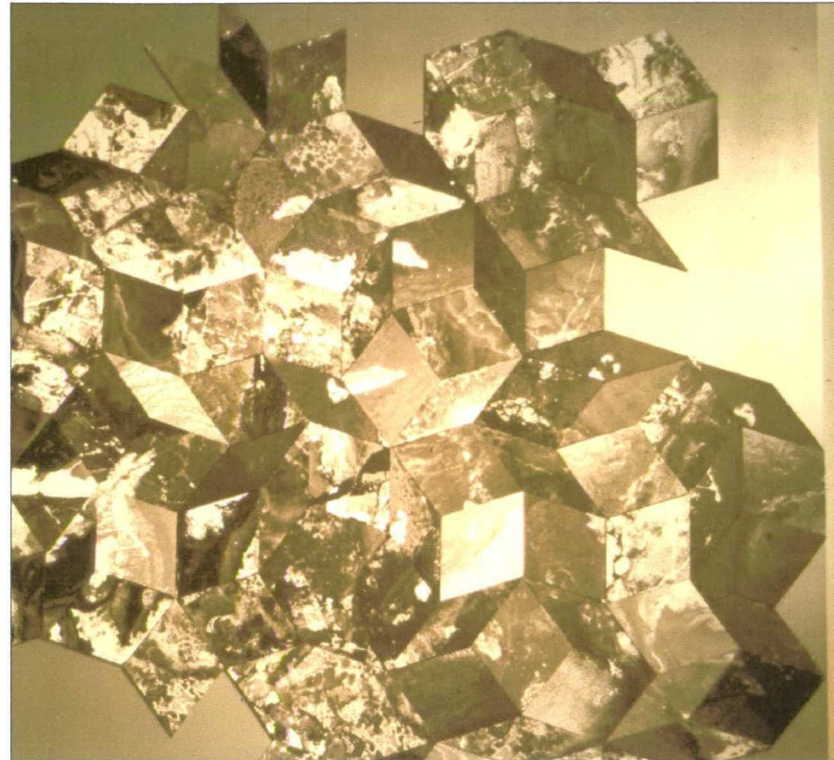
treatment but differing from the traditional functionally structured systems of ornament such as architrave, cornice or revetment¹. The project is not primarily about mathematics, symmetry or topological systems in Islamic pattern nor is it in the end about autonomous art objects. The strategic use of the computer drawing manipulation capabilities has provided new methods for the generation of linear based constructive geometric structures: structures for systems that could provide a rapidly formed and coherent aid to the creation of new design elements requiring a relational and logical form. It has been my quest to find a

way to adapt and expand on simple geometric principals that produce seemingly complex patterns such as the visually complex Islamic interlace and the modern aperiodic pattern systems formed using Penrose Rhombi.²

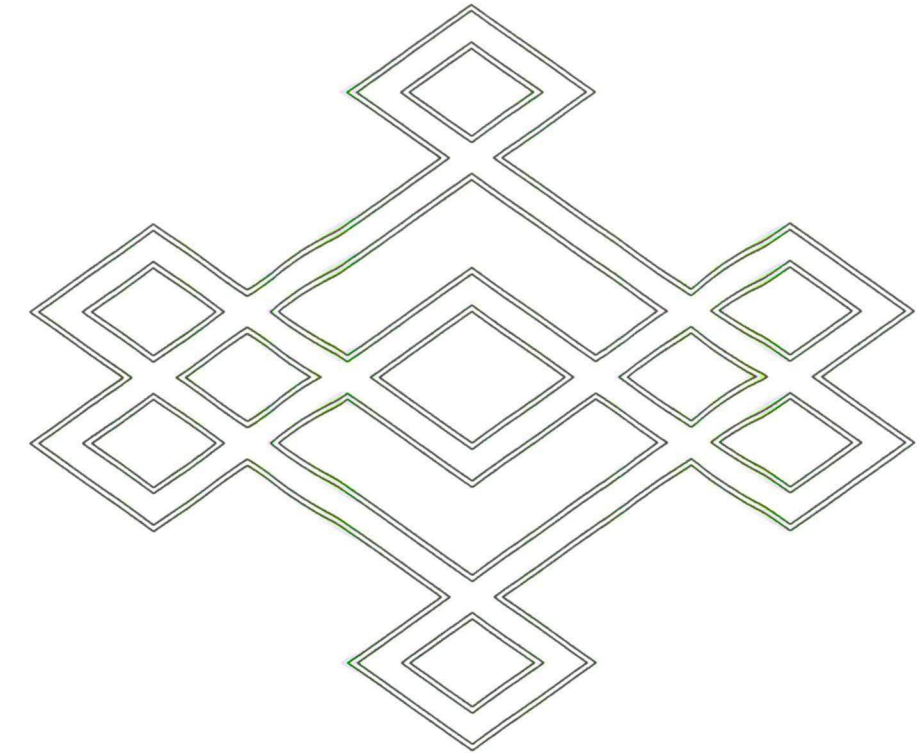
This project comprises three series of working systems developed in parallel: work that is interconnected but has

¹ Revetment is the term for tiling panels attached to the lower portion of building walls in Moorish architecture

² Roger Penrose *Emperor's New Mind, Concerning Computers, Minds and the Laws of Physics* Oxford Uni. Press, Oxford 1989 p.137 Detailed descriptions of Penrose rhombi based upon a five fold pentagonal symmetry, having multiple angles 36°, 72°, 144°. Matched to rule systems for the *generation* of aperiodic patterns. Aperiodic pattern is a non-translational arrangement of tiles.



1 Cluster of Rhomb tiles 100cm x100cm 1997



2 Knot Design 40cm x 32cm 1998

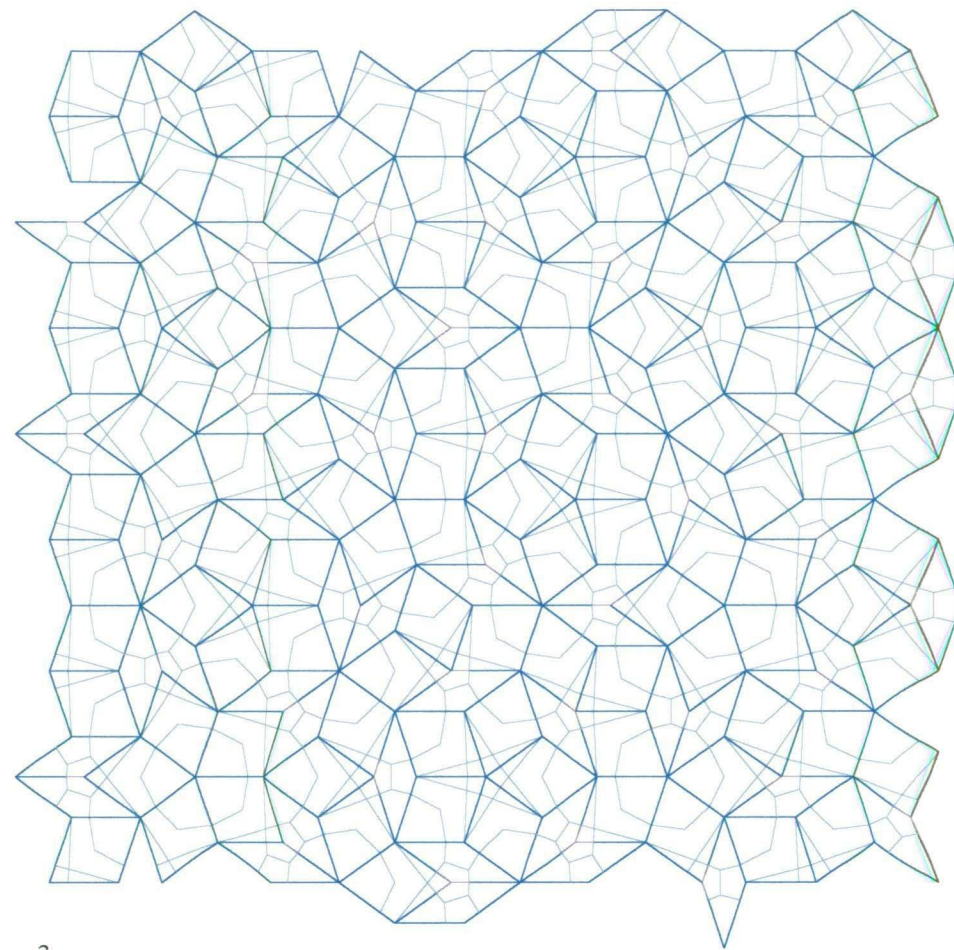
differing and diverse applications. The multi purpose systems have practical implementation possibilities in the arena of architectural façade enhancement and decorative wall and ceiling system design. The outcomes of the project have seen the strategic deployment of combinations of both old and new creative techniques and unique systems of practical geometric constructive logic re-invented for contemporary use. A multiple series of works carried out during my Honours year involved the production of a series of paintings using laser prints glued to modular tiling units³.

These moveable components were arranged in formations resulting in the creation of an object-image entity (pl.1). The geometric arrangements of tiles were attached to metal surfaces with the aid of magnetic mounts. The outcomes of the year's work gave an initial point for the commencement of further research into the aperiodic systems of five fold symmetric rhomboid forms.

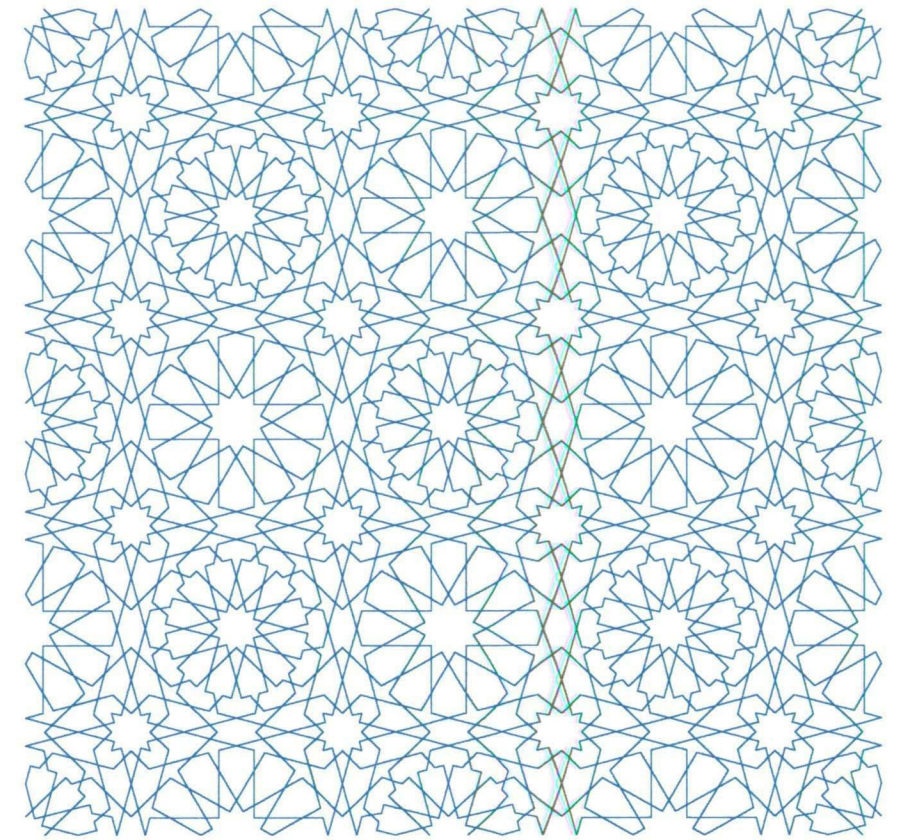
³ My Honours project included the production of paintings /interactive wall tiled images. Their primary concern was the aerial viewpoint, chiefly an area of interest centred around illusory information and deception principles that form part of military strategy, and the implications of surveillance and secret knowledge systems employed by the military. Extensive studio based experimentation and work saw the development of a specific system, needed and essential for the production of illusory pattern - pseudo satellite imagery.

The beginning of the current project began with Studio exploration for gallery wall based work and the drafting of the aperiodic geometric structural grid known as the Amman Bar Pentagrid⁴. During the drawing of this grid I began to find within the black line work on paper illusory three-dimensional cells appearing and disappearing. I found that the rhomboid forms were flipping from cubes to diamonds within the aperiodic pattern. This prompted me to investigate the idea of developing drawings of patterns applied to a rhomboid cell (pl.2) as an overlaid design.

⁴ 'Amman Bars Pentagrid' are a set of lines that cross each other in lattice form at angles of 18°, 36°, 72°, or 144° etc. It has been attributed to Amman.



3



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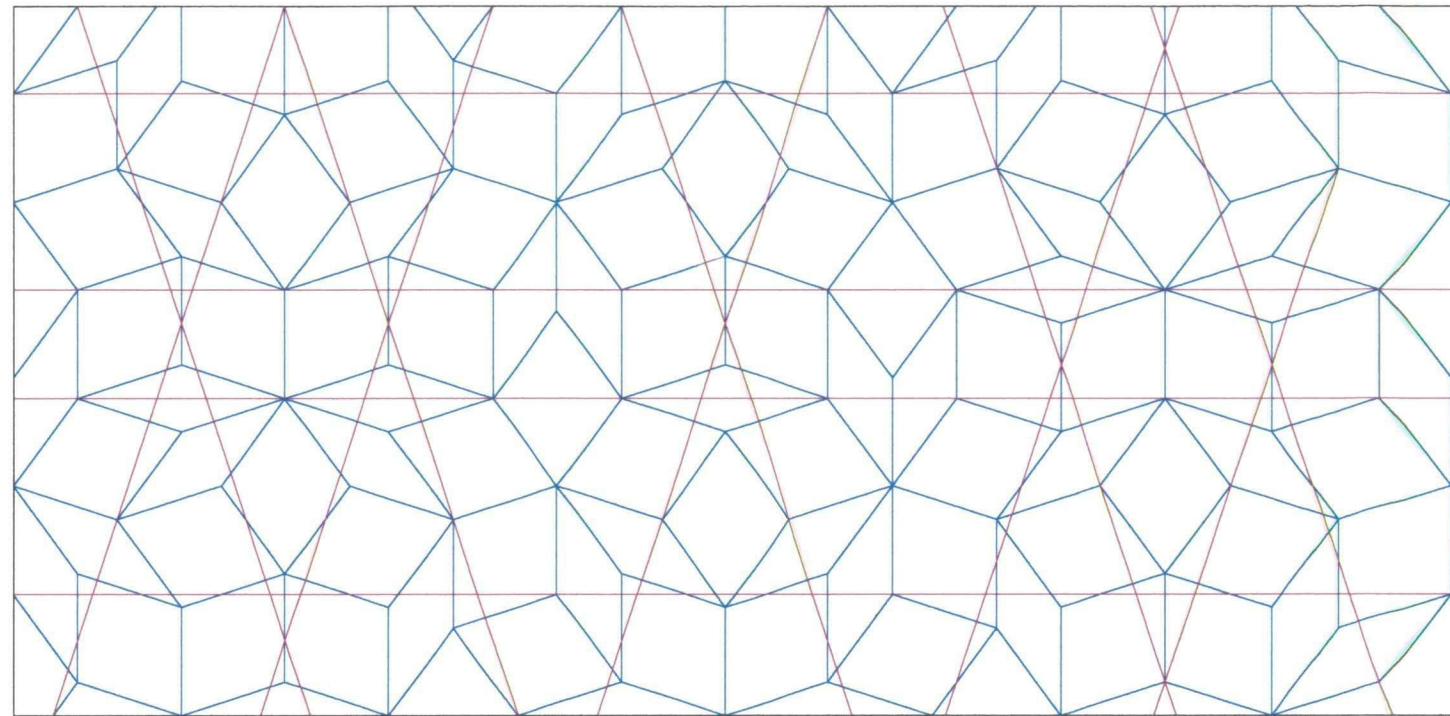
Initially it was considered as wall mounted tilings and that I might be able to design a new tile pattern. I began researching tilings with the particular characteristics that could be adapted to this rhomboid form.

Upon returning to the drawing board after a period of research in the university science library, reading about complexity theory, and non linear dynamics and looking at scientific diagrams of crystal structures being modelled with the use of the Penrose tilings (pl.3) I then set about dividing up the rhomboid cell using lines and angles generated from its diagonals. The resultant drawing took the form of a web of lines. Initially I began to broaden and strengthen the line work into a linear coloured element in

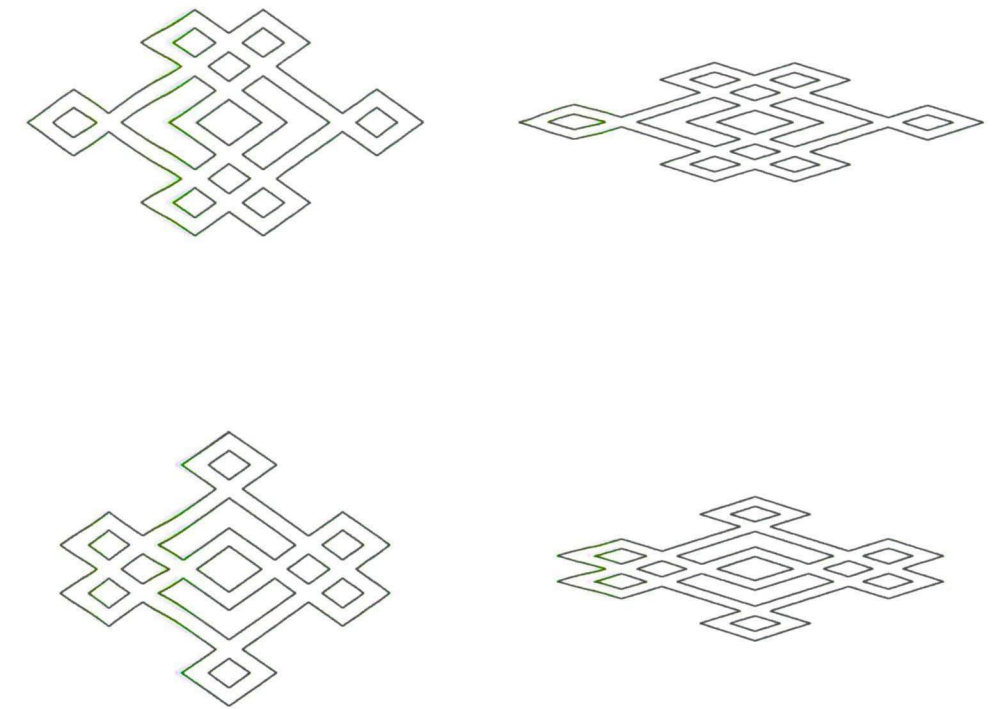
the form of a knot design which I drew on the paper, then pasted it onto thick card, cut up the drawing and made maquettes out of the Penrose rhombs. Experiments with combinations of these rhombs led to the development of wall mounted modules. A series of plywood modules in the form of the rhomb were tested and trialled on different wall surfaces and forms. I photographed and documented the various effects.

The initial experimentation with these modules saw the development and culmination of a linear knot-like design utilising the Penrose rhombi as hidden geometric substructure. This design is formed using a concealed geometric harmonic logic; its elements formed utilising the

$\sqrt{5}$ based spatial division of the rhomb. During this developmental work I had encountered many different forms of geometric diagrams of Islamic interlace, (pl.4) and I began to look at window grilles and Islamic openwork trellis. It occurred to me that a module could be designed that was a fusion of tiling and lattice. The immediate thoughts leapt to the repair work on a lute rose I had recently done. The modules that I was experimenting with at the time were solid plywood and card. A decision to cut through the card with a knife and form it into a lattice resulted in a lattice module (pl.7). I have coined the word 'Latt-tile' to describe these series of modular units. Analysis of the Amman Bar Pentagrid lines that form all



5 Amman bar pentagrid with Penrose Rhombi



6 Latt-tile set

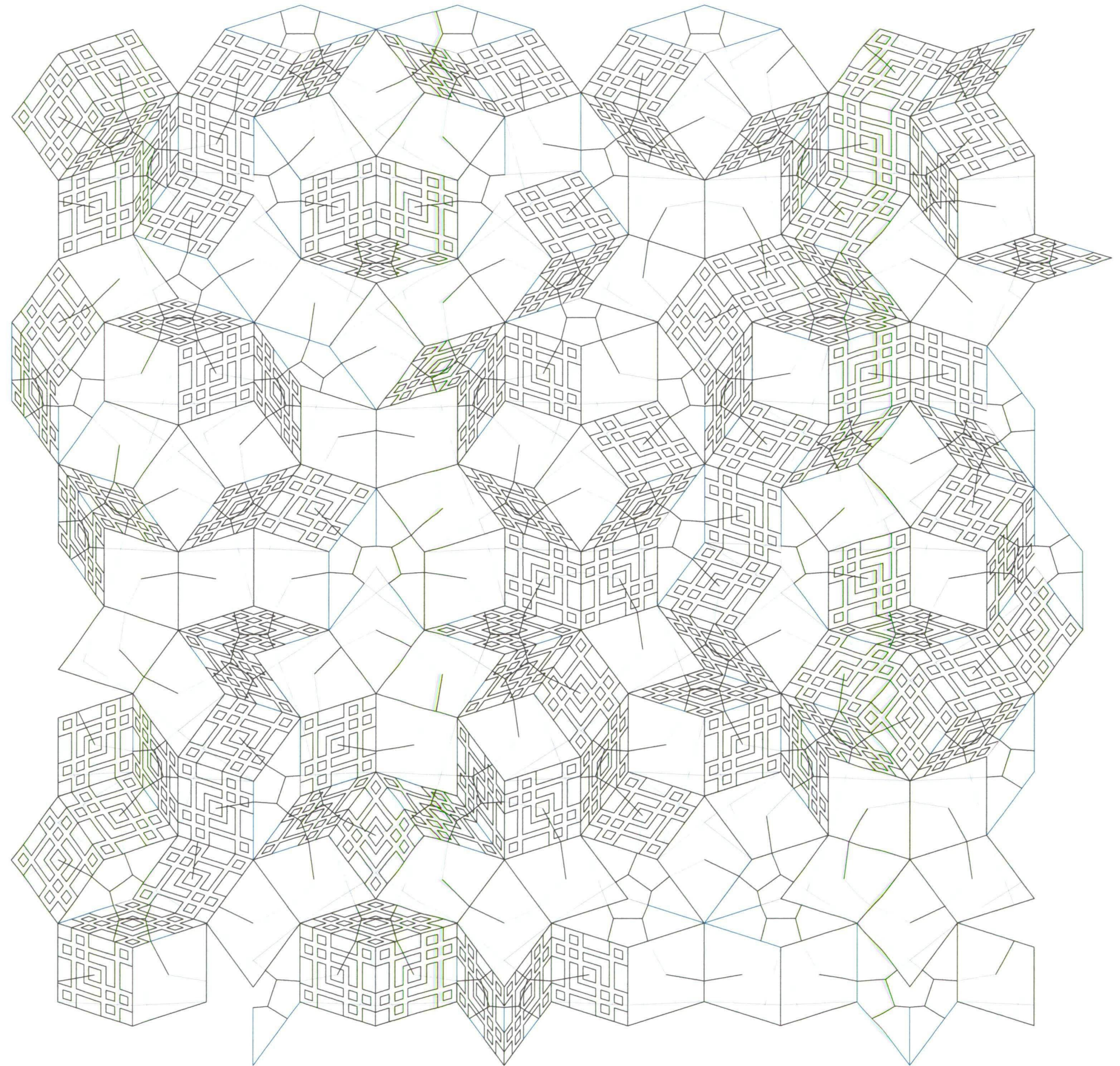
possible points of intersection for the aperiodic Penrose rhombi (pl.5) and Islamic geometric systems has aided in the design of rhythmic harmonically generated overlay systems of lattice for variations of the Latt-tiles (pl.6-7). One of the first and important findings was that an applied floating lattice or tiling system such as the Latt-tile visually reinvigorates dull planar forms or surfaces. The potential for multiple layers of appliqué or modules can provide a graphically geometric linear system of building ornament that can be both structurally functional and have a kinetic role. The kinetic aspect of building mounted modules arises from the play of ambient light and shadow resulting in

building mounted ‘illumination’ articulating linear re-vitalisation and vision.

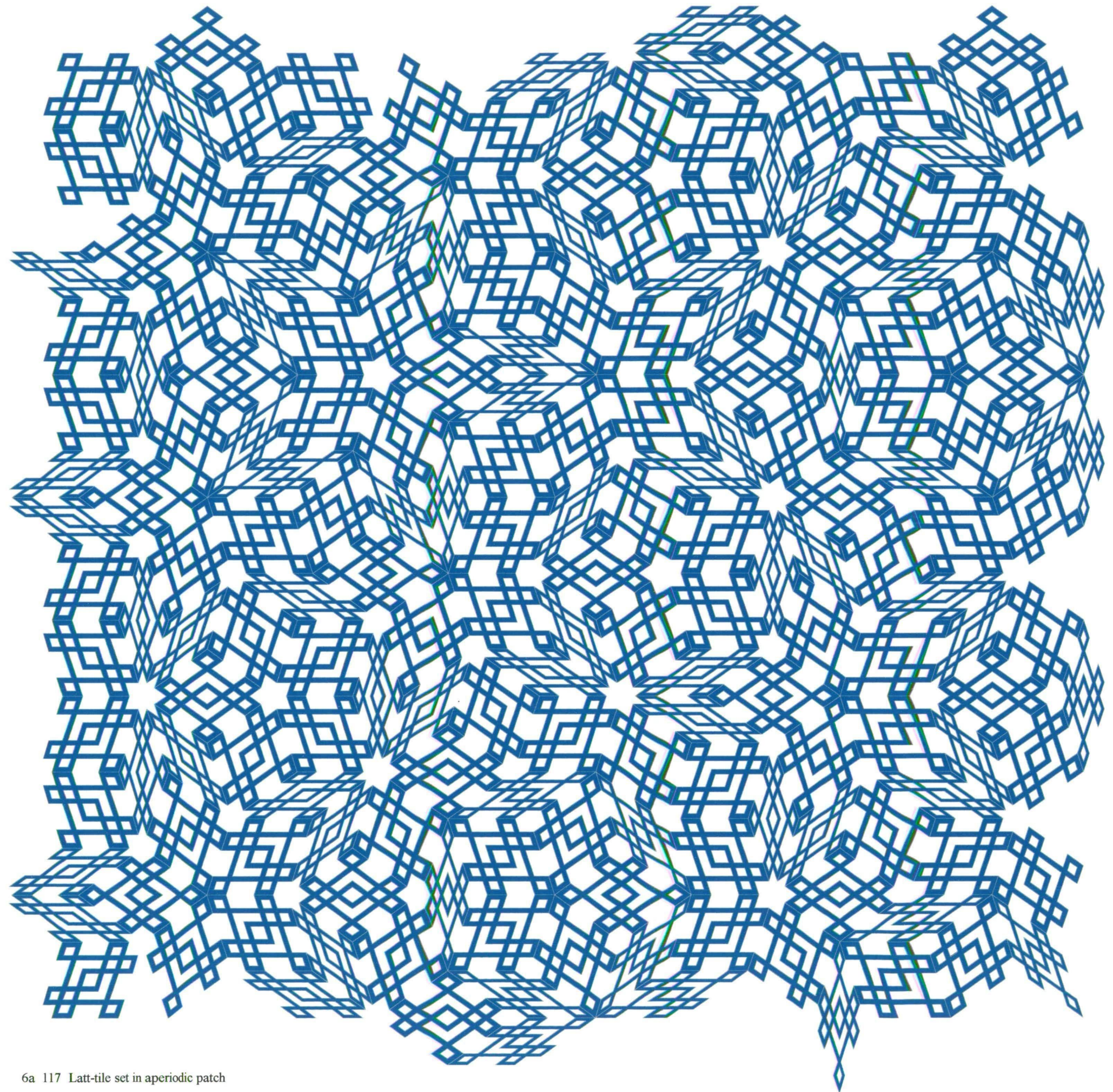
Early prototype gallery functioning pieces allowed the subsequent adaptation of the rear light reflective properties, shadows and illusory spatial effects of the lattice. The testing of various materials and coatings, such as high-density luminous pigments applied to the rear surfaces of the units, resulted in a variety of coloured shadow effects that can be enhanced by the creative use of lighting systems. Multiple light sources give multiple shadows. I experimented both with light sources and variation of the offset mount dimensions using harmonic projection of light

beams to test the depth and intensity of shadows cast by the shape and line of the Latt-tiles. During research of ceiling decorative systems I discovered an important primary source of inspiration in Bourgoin⁵. This volume has been integral to the whole project. This primary resource document is a collection of plates of hand drawn geometric and analytical line samples of Islamic design layout drawings. It contains line drawings of all seventeen known symmetry groups together with tiling systems for the walls and ceilings in the Alhambra Palace, Granada.

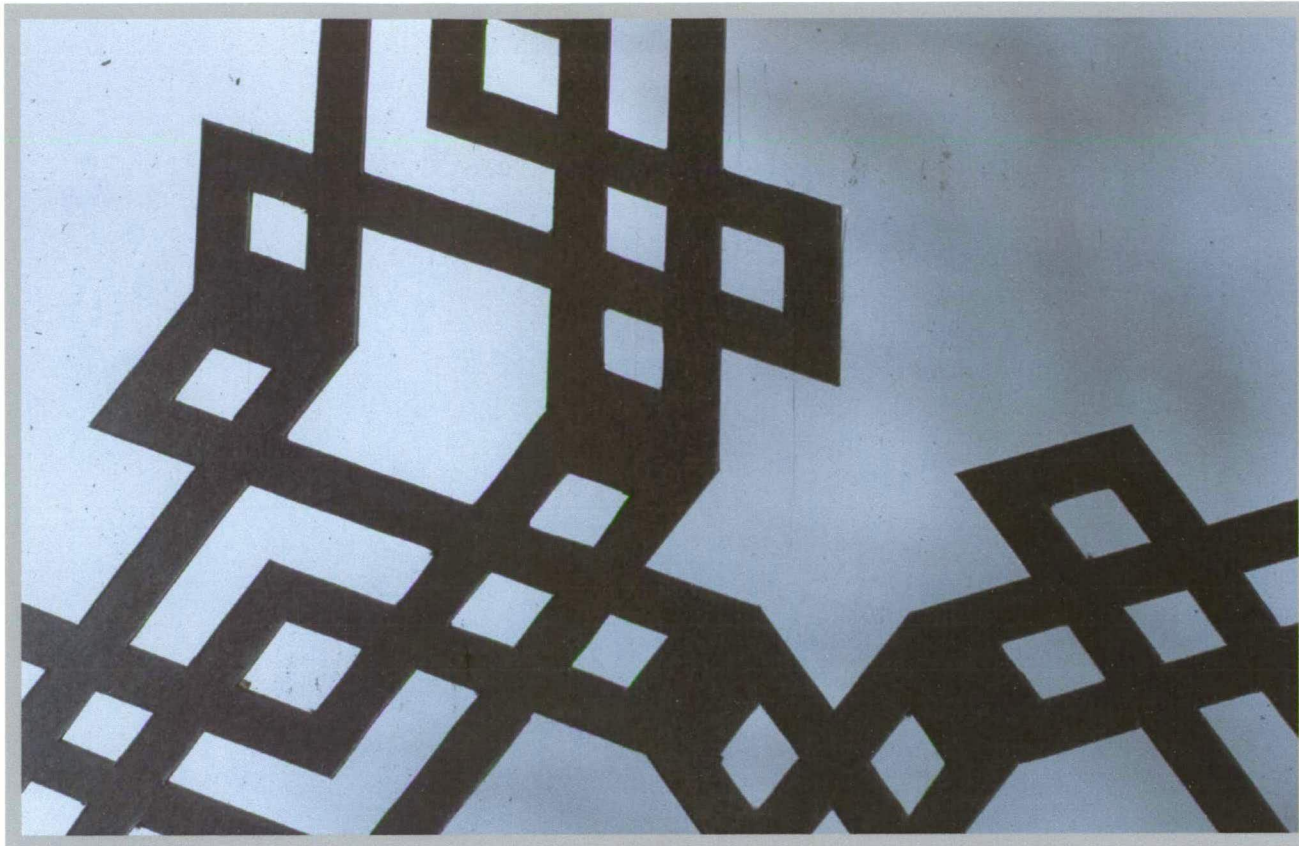
⁵ J. Bourgoin *Arabic Geometrical Pattern, & Design* Dover Pub. NY 1973



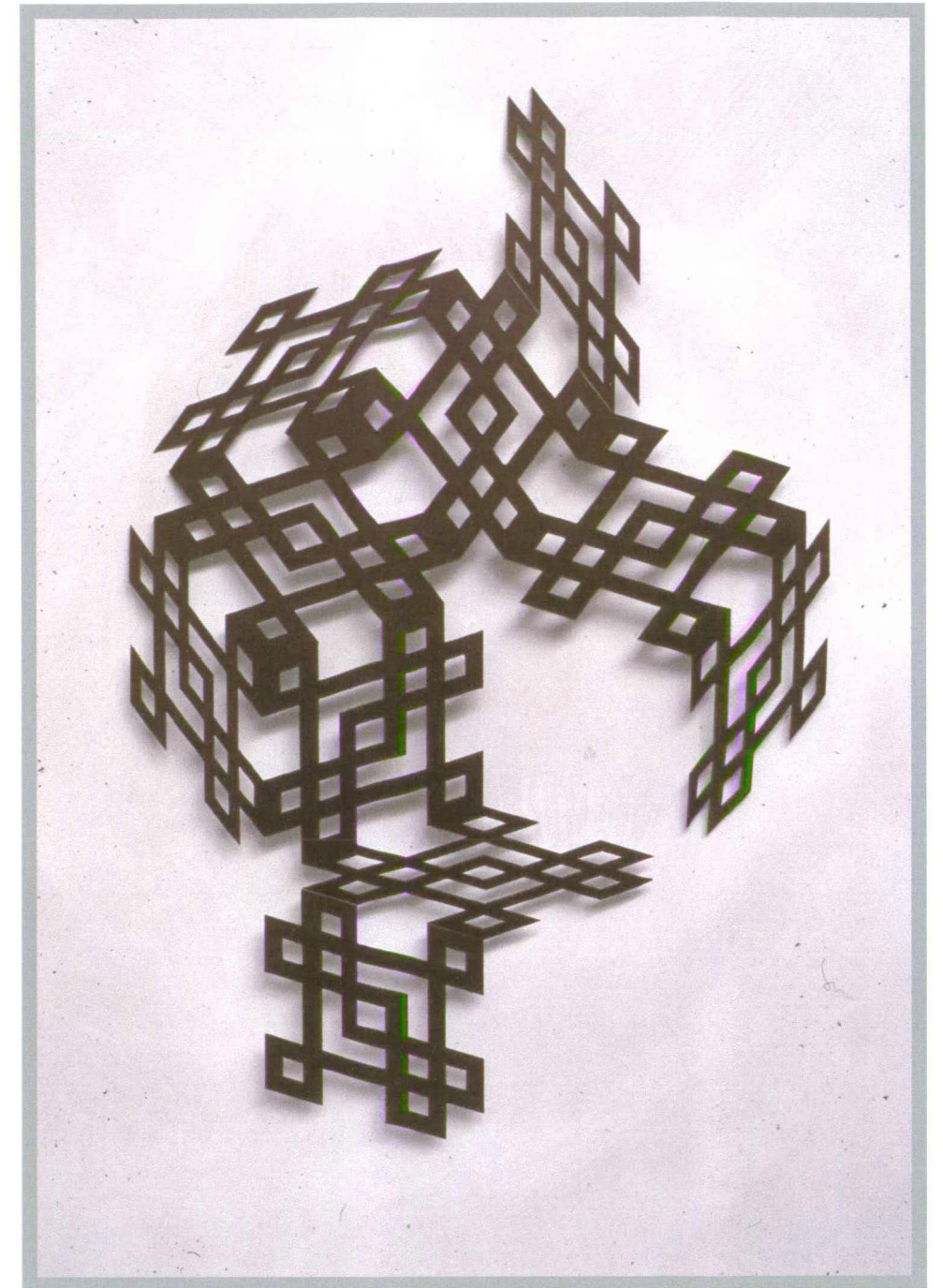
6a Latt-tile sets in aperiodic layout construction drawing



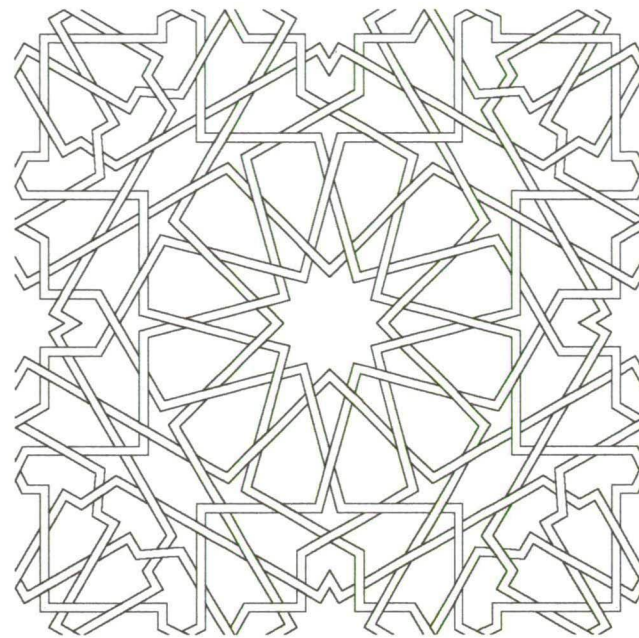
6a 117 Latt-tile set in aperiodic patch



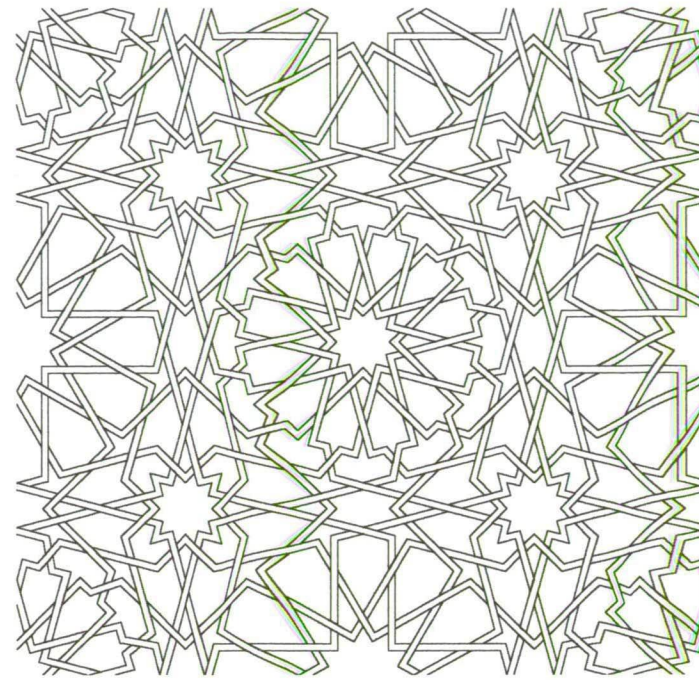
7a Detail of Latt-tile



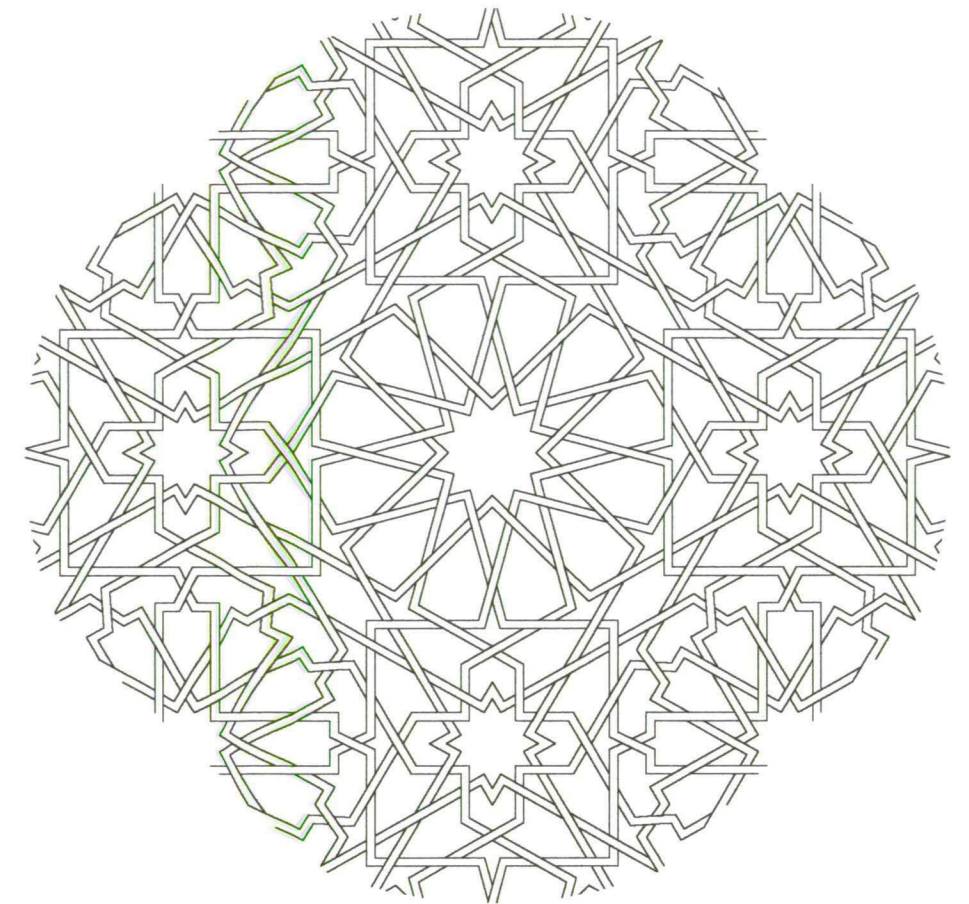
7 Latt-tile 1998



8 Major twelve flower - originally drawn by compass and straight edge



8a Minor twelve flower as centre with corner squared links



8b Interlace rotated 45 degrees - revetment Hall of Ambassadors Alhambra

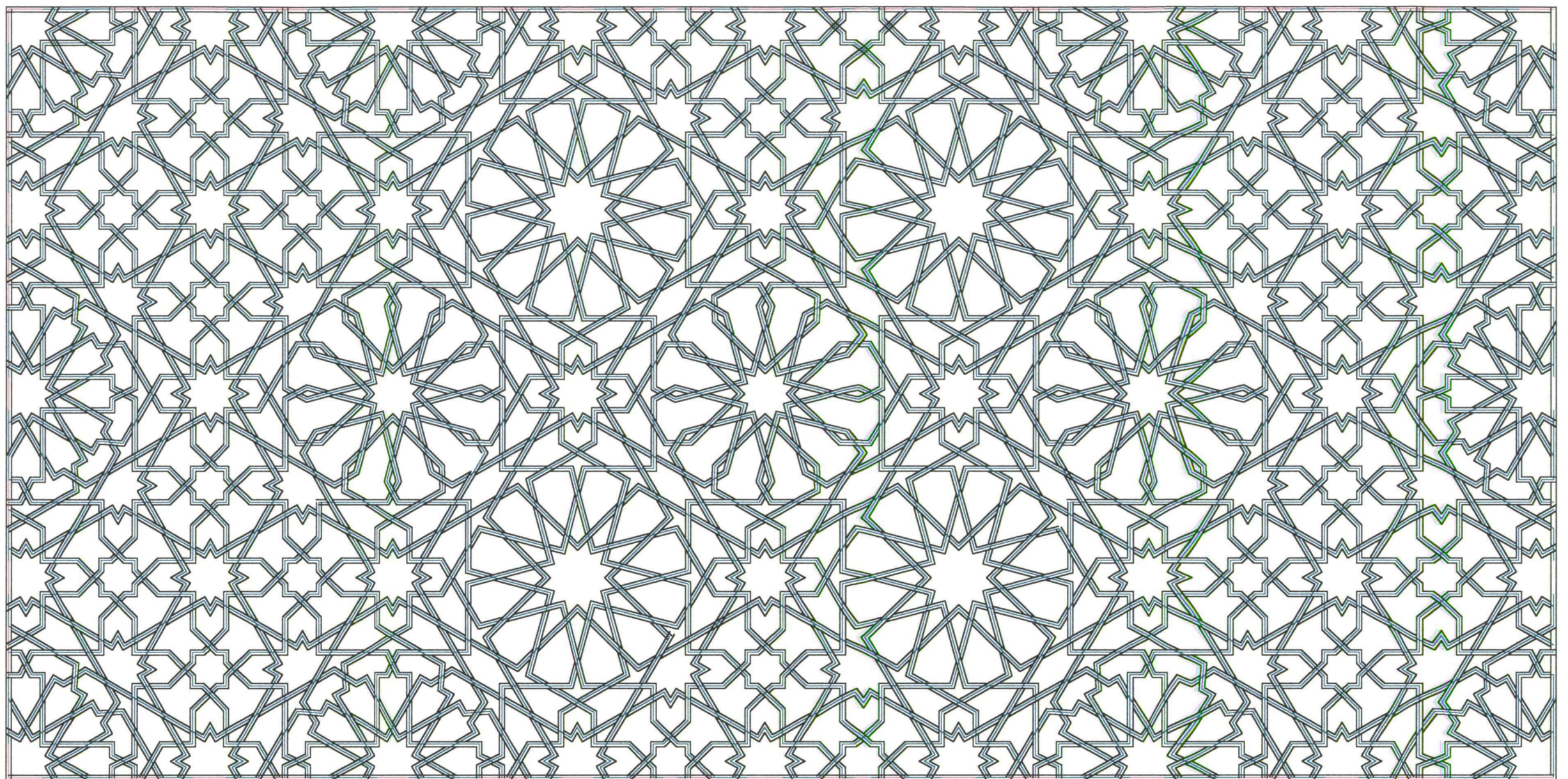
Long extensive drawing sessions were needed for working out and studying the geometry of these interlace pattern systems in order to discover a deeper level of structural organisation and to find a grid or structure for the overlaying of Latt-tiles. During the process of developing the skills to draw these complex constructive lattices I had to take periodic breaks. Working continually over the top of a drawing, maintaining a system and keeping a coherent sense of viewpoint is difficult; normally drawing systems maintain a hierarchical 'weight' of lines, otherwise the combined complexity of working with hundreds of lines at once can become visually confusing (pl.8). The ambiguous

nature of the myriad of lines can induce a form of hallucination. This effect became a source of fascination.

Some plates in the Bourgoin document include an analytical dotted construction line explaining the systems of arcs, divisions of circles and angles, of lines and points of intersection. An ongoing fascination developed with the construction line drawings themselves⁶. A property of the construction lines is the intriguing moire effect of complex even-weighted lines on a white surface. The Bourgoin

⁶ Construction line is a line type in technical drawing; a very light weighted pencil line for assisting drawing development. Usually as the drawing is evolving, it is strengthened to outline.

diagrams are drawn on the Euclidean plane and therefore have no thickness. When they are viewed on paper the oscillating effect creates a moving third dimension that visually attracts and repels. Particular drawings that have this effect were studied for elements that could be extracted as a single entity, a bounded object that could be made into three-dimensional forms. The magnitude and the variety of skills needed and the mechanical processes involved, both in the design and construction of the wooden or tile components of the ornamental revetments, wooden domed ceilings, windows and open work such as in the Alhambra, is staggering. Notwithstanding the fact that I am skilled in deciphering line drawings, I found the interlace line work



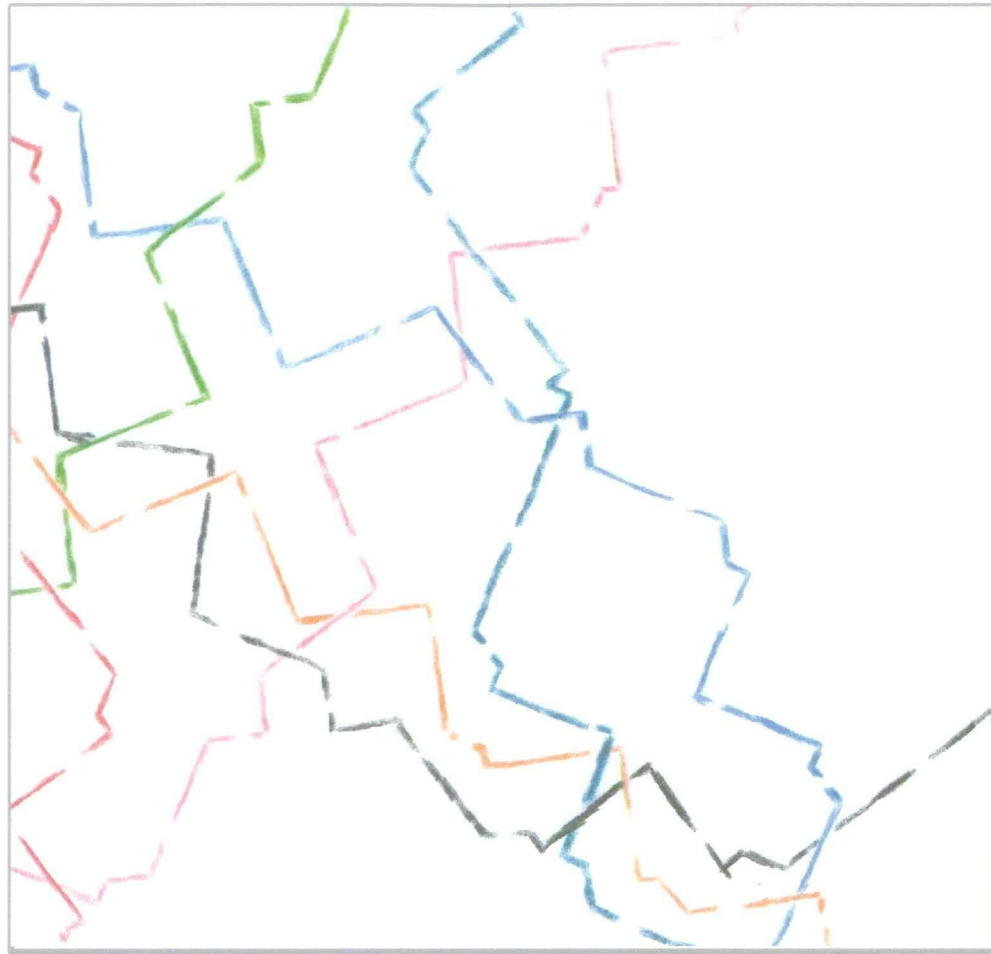
9 Drawing of Ambassador Interlace CAD 2003

very difficult to keep track of. The enormity of the task required to produce them was immediately apparent. A fellow practitioner or trades-person can easily recognise and appreciate the sheer scale and perfection of the joinery, and the relentless effort that has been employed in the pursuit of their perfection. My education and training in the carpentry and joinery trade, combined with acquired skills in architectural drafting, has equipped me with systematic tools for the analysis, comprehension and dissemination of the geometric construction line drawings.

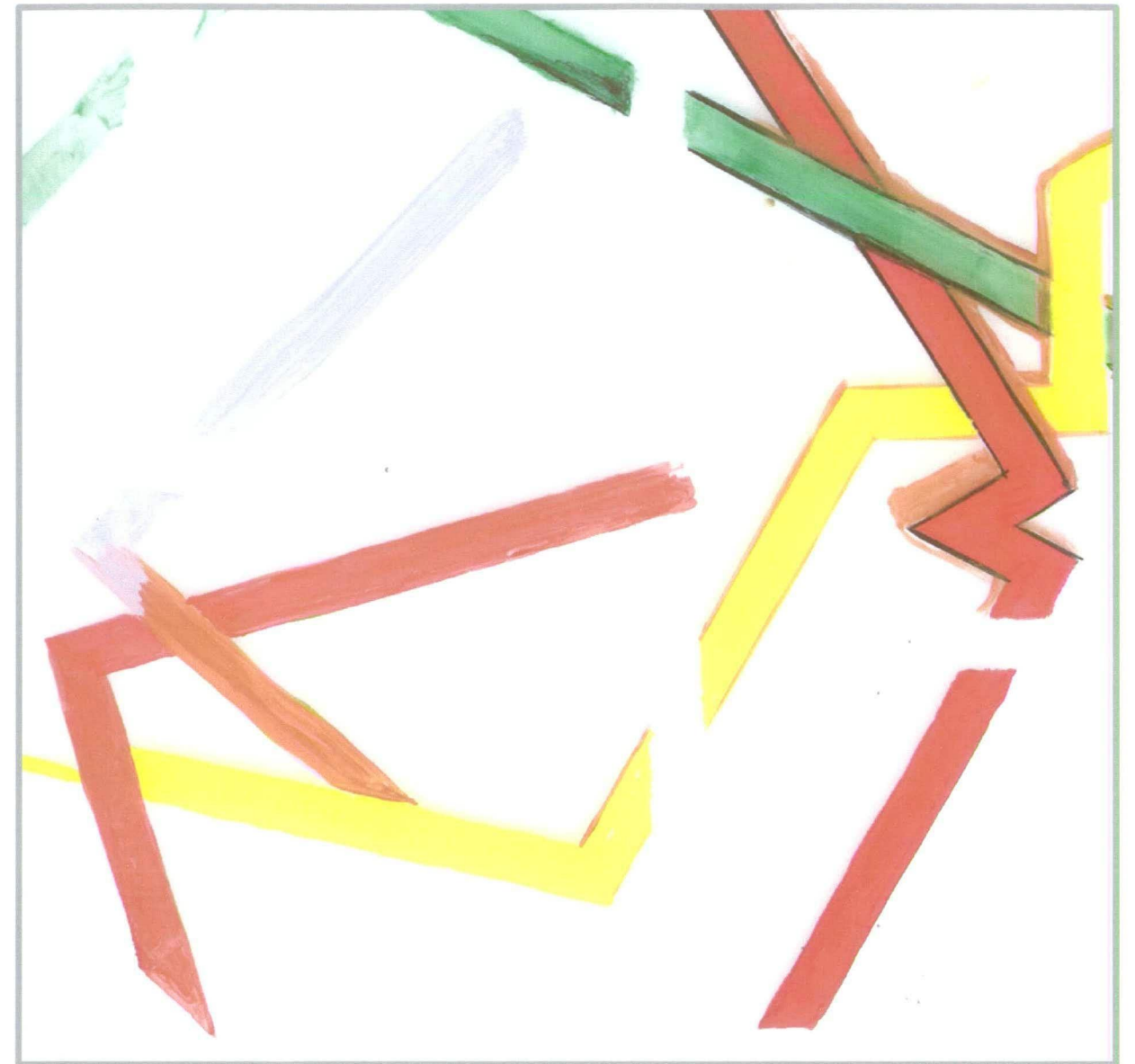
When the term 'Islamic pattern' is used in this document, it is referring specifically to the interlace pattern. Not all Islamic pattern takes the form of interlace and I am not concerned with other forms of tilings although they can be formed using the same systems. I am particularly interested in the linear pathway elements within the interlace designs (pl.9).

I began to explore the traditional drawing methods that were used to create these designs. Using a simple compass and straight edge, the original designer of the interlace would determine the thickness ratio of the path or line of

the pattern by joining neighbouring interspaces ie. lines from two adjacent cells or elements. I set out to find out how this was achieved. I started by using a drafting table and engineering drafting machine, compass, dividers and setsquares. Working by systematically developing each construction drawing line in a sequential and controlled process has enabled me to experience first hand the basic tenets of this form of geometric reasoning. Each successive drawing layer uncovered amazing coincidences and points of harmonic relationship between individual sections of line. Having to experience the process, be immersed in the drawing and take it in through the hands rather than the



10 Interlace pathway mapped with coloured pencil on drafting film



10a Painted pathway on drafting film

mind, is a form of trade indenture. With the aid of Keith Critchlow's analysis⁷ I drew the Moorish interlace design from the Hall of the Ambassadors, Alhambra. I photocopied this drawing, a 600mm x 600mm square, reducing it to 100mm x 100mm. One hundred copies were taped together to make a metre square tiled array panel of this pattern. This larger interlace sample was used for the analysis of the interlace pathways. I methodically and systematically

mapped each member element's pathway using different coloured pencils. It required a way of scrolling a sheet of drafting film over the interlace panel drawing, because constant re-positioning over each new cell was needed to continue mapping the elements (pl.10-10a).

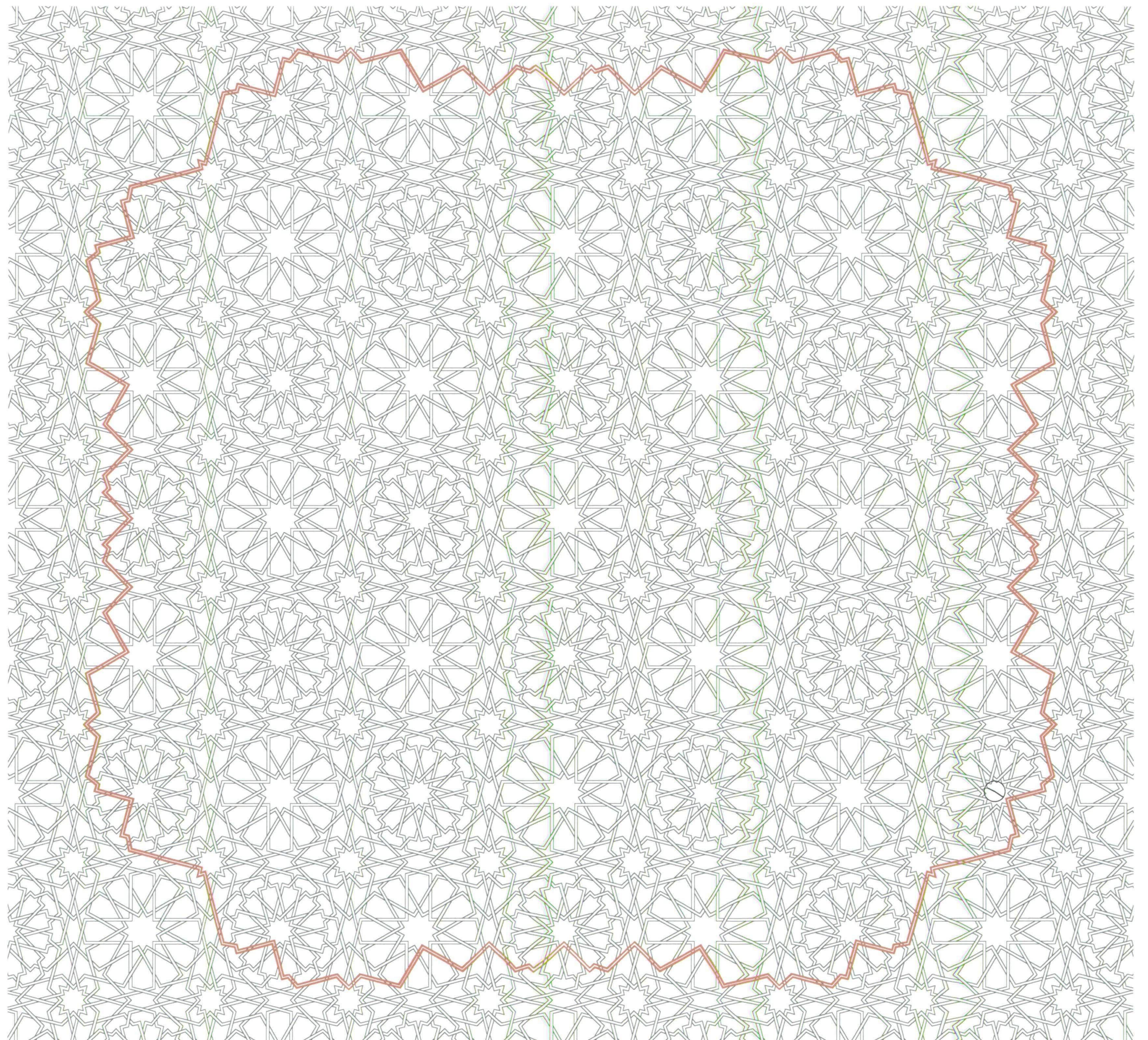
This process proved a practical solution to gaining insight into the operation of the elements' geometry within the design. Mapping the pathways in colour led to the uncovering of a 'Recursive Loop'⁸ (pl.11) a unique feature

⁸ Recursive loop is an element of the interlace which, originating in a core cell star flower, expands out to the edge of the cell and due to the symmetrical elementary under and over logic of interlaced pattern it is carried on, not to infinity as some of the grid elements are, but returns to its origins after visiting each cell.

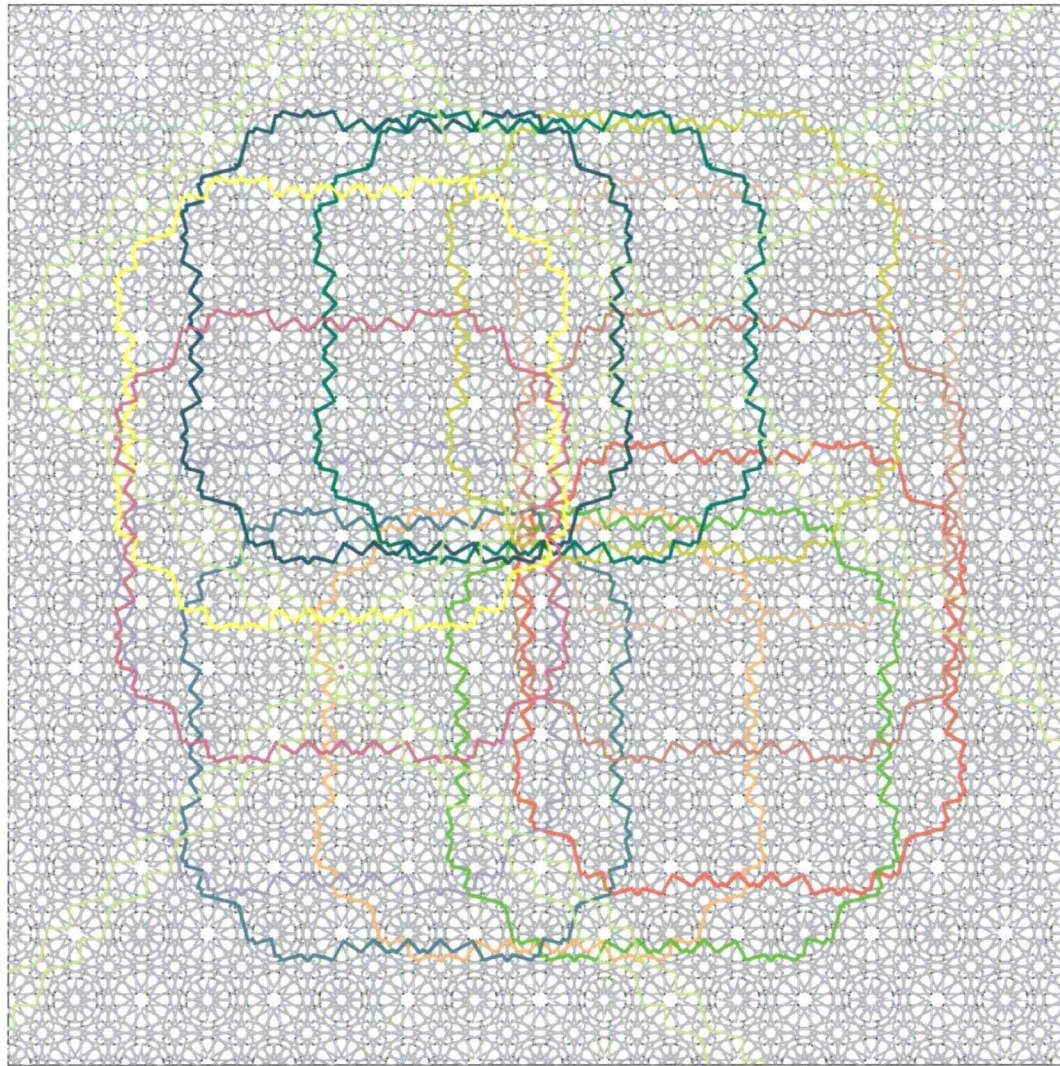
within the kernel of this particular interlace. Further scrutiny of other interlaced patterns revealed that this feature was largely unique to the Ambassador design. This drawing revealed some of the mathematical beauty and science hidden within the line framework of these tessellations.

The interlace pathway is unique in the under and over interlock enmeshing of a linear element. The more sophisticated of these designs have a variety of systems happening together, cleverly morphing from one symmetry system to another. These patterns are not simply repeated cells based upon a grid. The grids are there but only as a

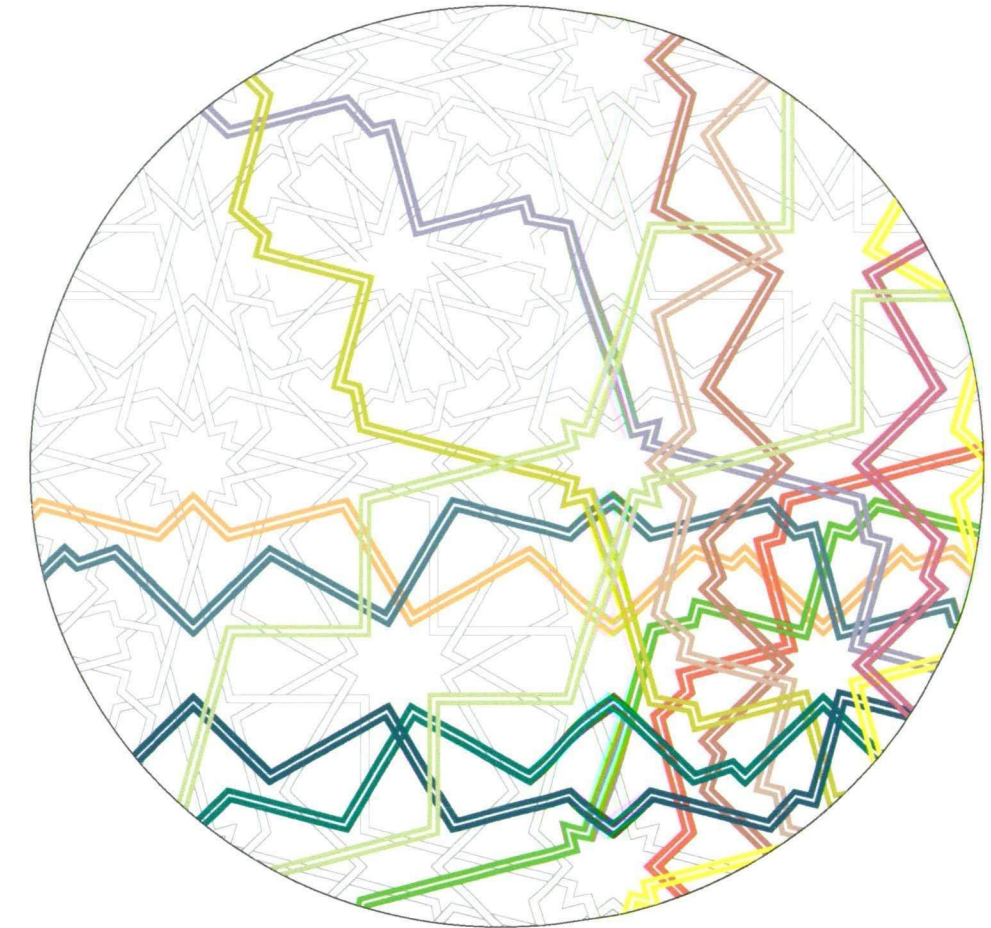
⁷ K.Critchlow *Islamic Patterns An analytical and Cosmological Approach* Thames & Hudson, London, 1995 p.180



11 Hall of Ambassadors interlace 64 Cells of drawing showing full recursive loop.



12a Flower cell mapping set of recursive loops



12b enlargement of central cell

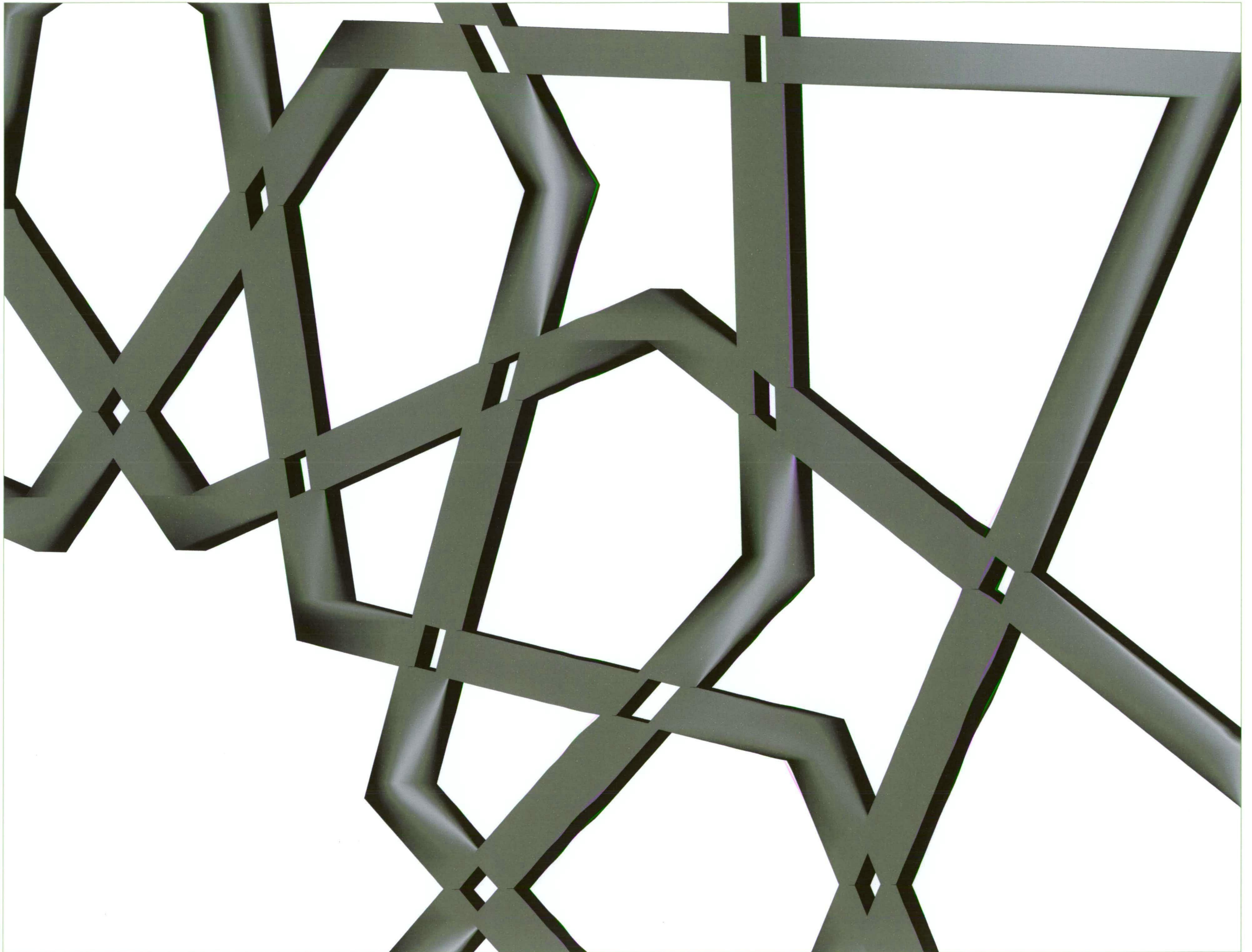
consequence of the harmonic logic. It must be pointed out that the grid is not the structure that produces the complete design – it is one element of many. The knowledge of how it is created is within it, enmeshed within the underlying constructive geometry.

It became evident that drawing by hand or tracing repeated cells of pattern to obtain working practical examples to study and experiment with was too tedious and time consuming. Therefore the move to computer aided drafting (CAD) was essential to be able to advance and develop drawings in a digital format that could be used as templates, or assist in the processes for the technological design applications.

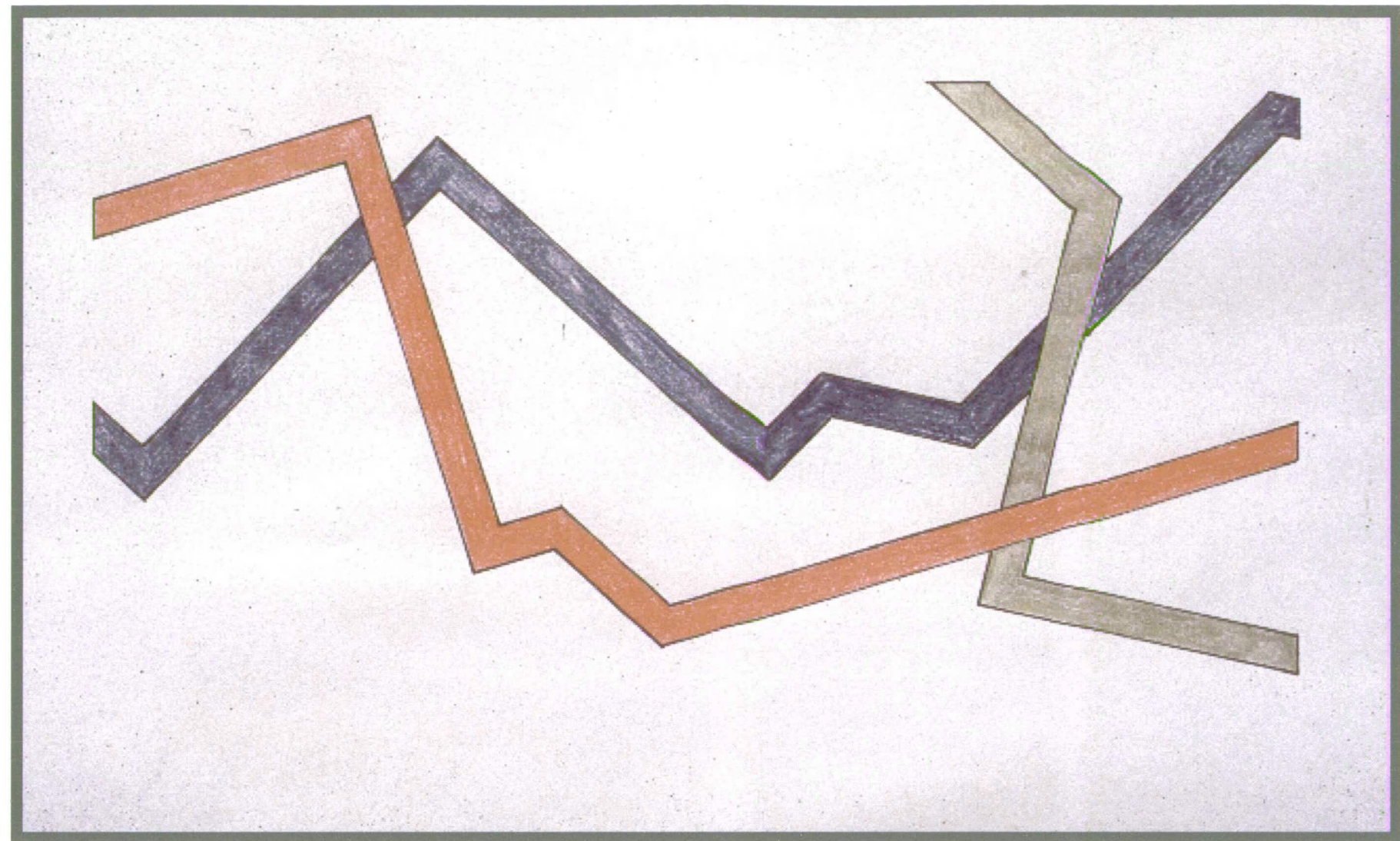
It was through a strategy of deduction, trial and error, and testing one method against another in a geometric sense, that I could figure out which drawing constructive technique was used and what can be achieved. The move to CAD has allowed the development of concepts utilising the knowledge gained through the study of the interlace geometry (pl.12). The aim of this project has been to extract information and bring it into the modern CAD three-dimensional modelling environment for use as a design aid in the generation of new forms of object⁹.

⁹ It is not simply a matter of buying a program! The Cad user interface has the tool-bars or mechanisms for drawing models and templates for use within all computer aided drafting software

The intention of the project shifted to the expansion of the CAD developmental work using elements such as the 'recursive loop' and developing methods for the practical application of the project's multi purpose systems in the arena of architectural façade, wall and ceiling decorative system design. For me the move to the CAD infinite virtual space, where drawings are done full size and no scaling is needed, has given greater freedom and unlimited potential for developing new methods and techniques for conceptualising and evolving new geometric frameworks. It allows me to create and manage complex drawings of the underpinning linear based constructive grid structures so that they can be converted from two-dimensional drawings



12c Interlace CAD 3D Drawing rendered image 2004



13 Inter wall piece 1999

to three dimensional modules or objects. The modelled structures can be used as a rapidly formed but coherent aid to the creation of new design elements - a virtual product having harmonic and relational logic form. The ensuing elements form the starting point for the creative development of new three-dimensional objects. These object units or modules can either be incorporated within façade design or superimposed on existing structures, like a drawn element, or hung above the surface or facade of a building. They can re-vitalise a planar surface: the essential product - a 'floating object' over structure as drawing (pl.13). A fusion of modern CAD processes together with my preceding historical trade/craft drafting and carpentry

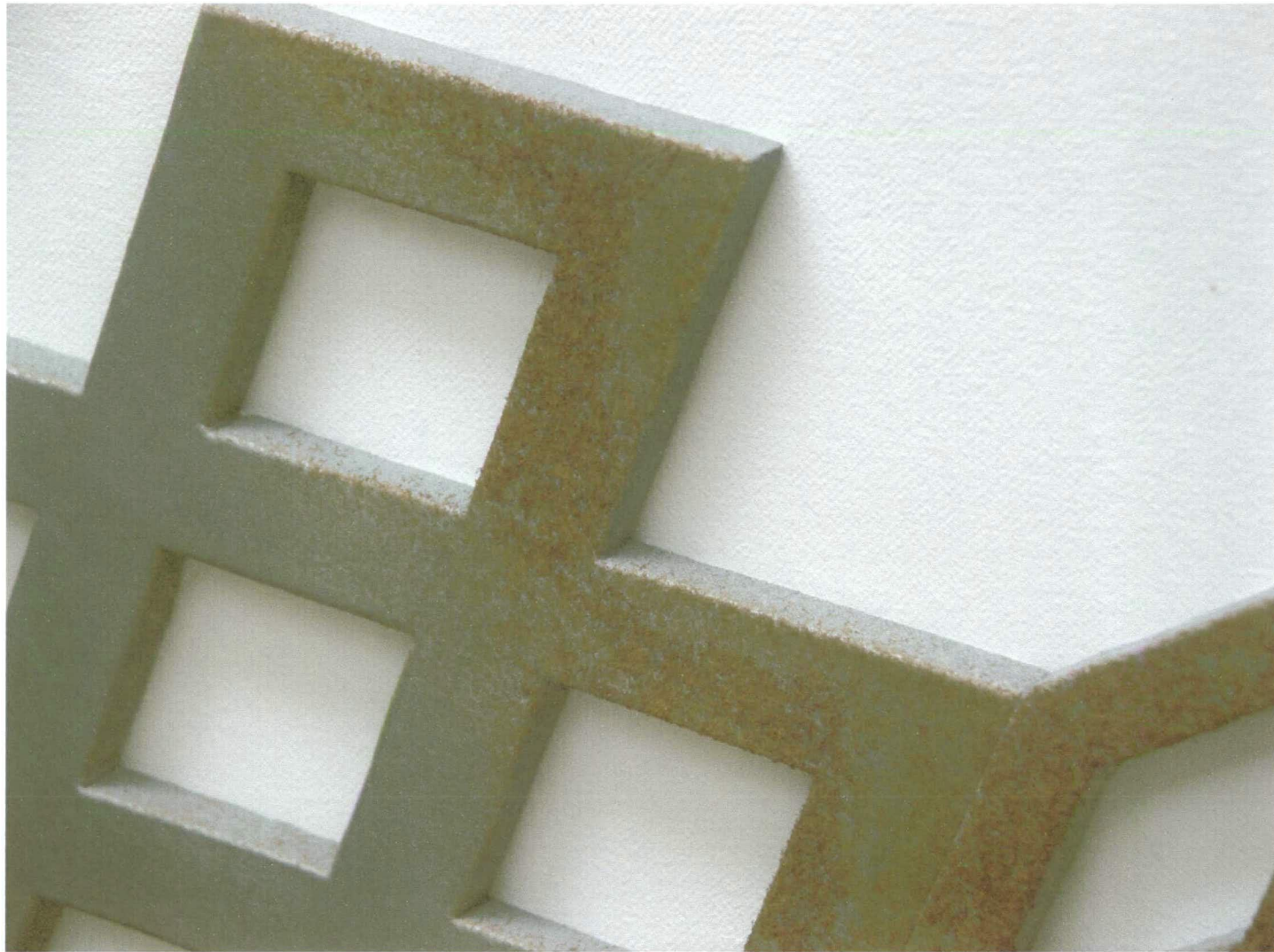
skills has widened the outcomes of the project: has seen both old and new creative techniques, unique systems and practical geometric constructive logic reinvented for contemporary use. As Jane Pavitt states...

A New Craft Practice? There are parallels between the use of CAD and the idea of craft practice. The separation of the design process from the process of fabrication is a characteristic of 20th century industrial design, but not craft production. As design writer Tom Mitchell once put it: "The idea of 'The product' as an object considered in isolation from its context of use did not exist before the advent of industrialisation, nor did design professionals who planned, but did not construct products. Before

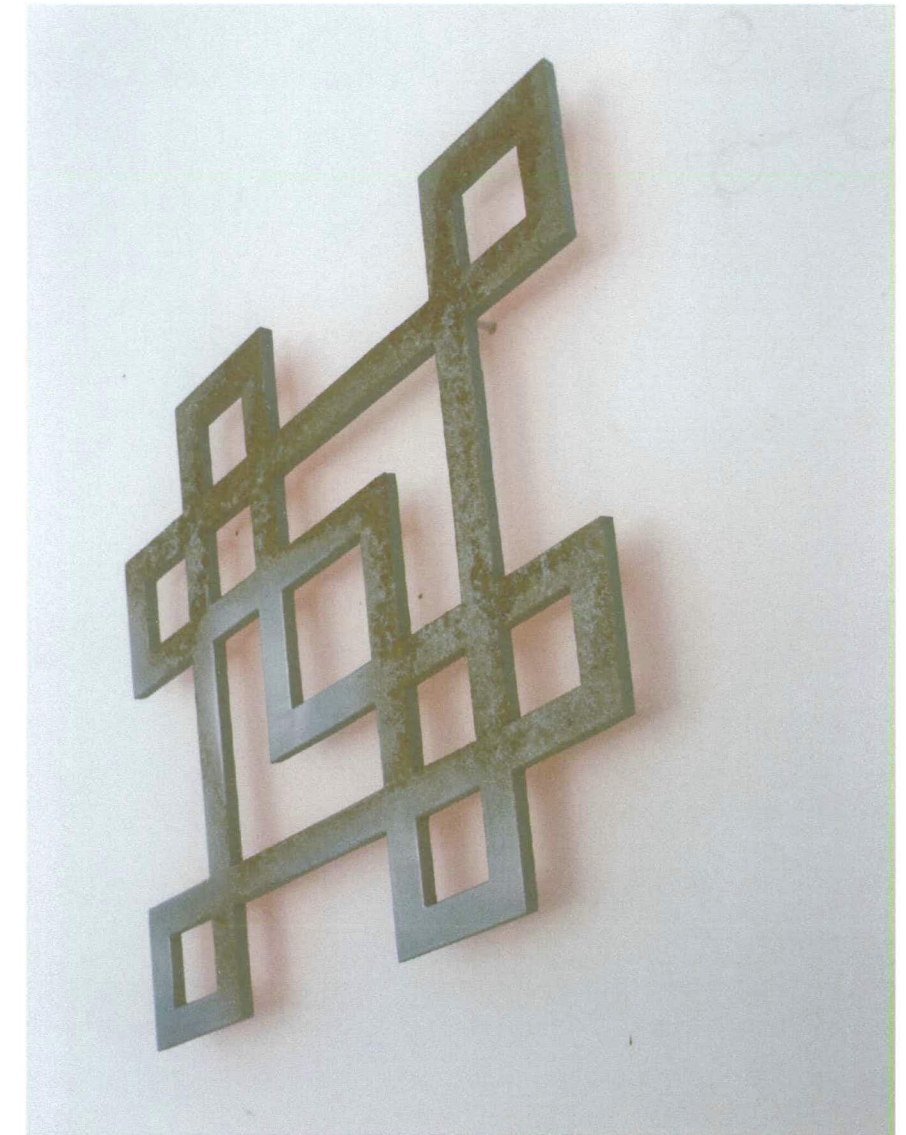
industrialisation objects were made using craft processes in which the planning and making of objects were inseparable aspects of the same processes."

The inseparability of planning and making is also a characteristic of Computer Aided Design, Malcolm McCullough and Peter Dormer, among others have argued that the use of digital technology is itself a form of craft practice, where the hand-mind split engendered by industrialisation is restored.

Designers should be able to embrace the possibilities of CAD, not only as a more effective substitute for the existing



Detail Latt-tile 2004



Latt-tile with yellowed metal finish aluminium and forrest on mdf substrate

stages of design development, but as an alternative form of creative thinking.¹⁰

Using the inherent relationships within the scrutinised geometric orders, new designs were evolved which expand upon the harmonic relationships of the original elements. Using these notions, the potential for multiple layers of appliqué or modules is unlimited and will provide a graphical geometric linear system of ornament with a structurally kinetic function, 'inclusive as structure'.

Reflection, lustre, refraction, luminosity, darkness, colour,

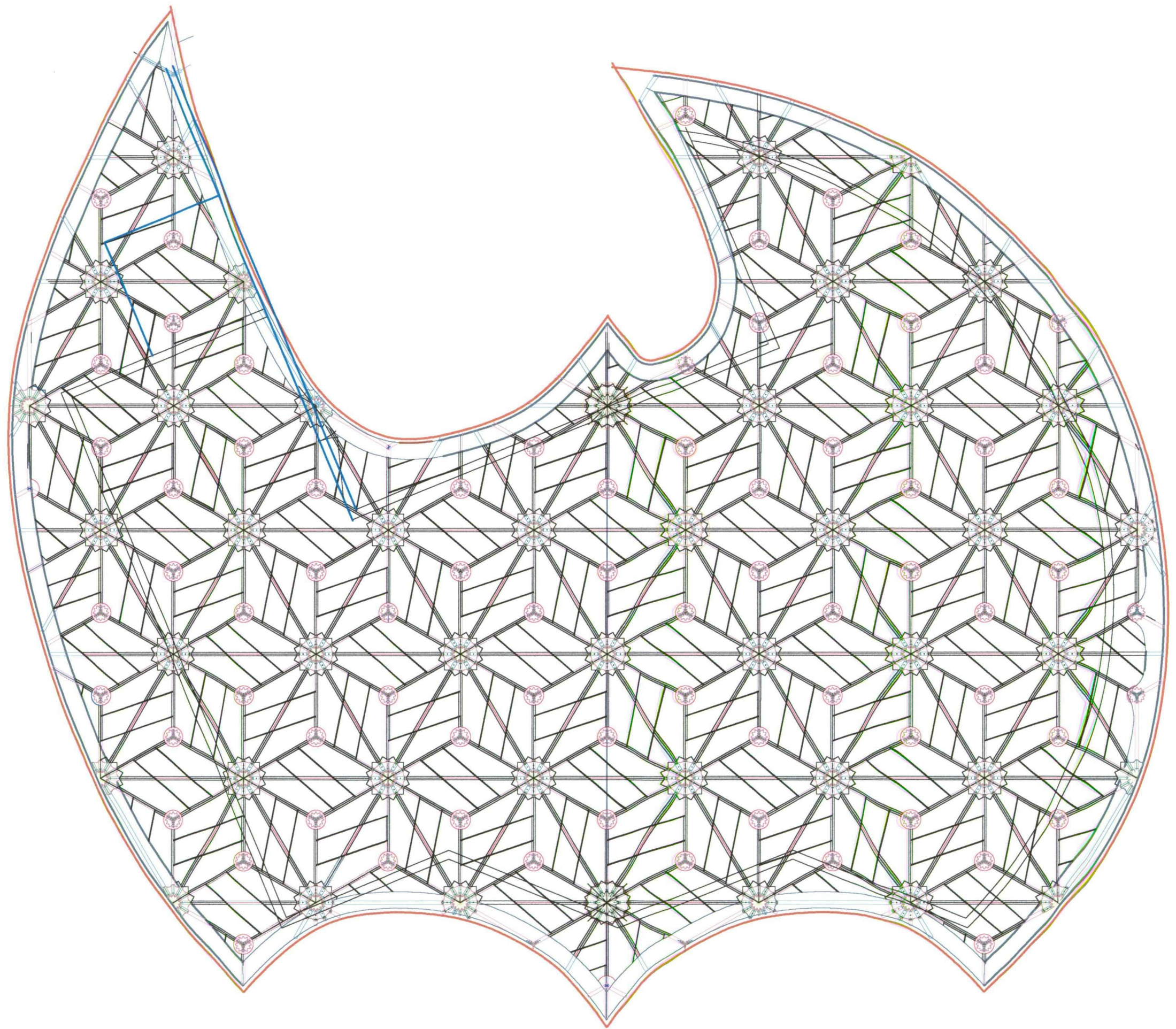
softness absorption, liquidity, atmospheric density, instability of shape these and a host of other properties jeopardise perceptions of metric uniformity. It is perhaps ironic that the first challenge to Euclid came from mathematicians who were reputed to have stripped the world of these properties... Geometers had escaped from geometry; architects might escape from architecture Poincare thought our definition of space should be decided on grounds of practicality.¹¹ This project "Systematizing Randomness: A New Decorative Order" develops three

unique systems of ornament which can be incorporated within the architectural integrity of a building design or applied as self contained fragments or clusters, free of any bounded edge.

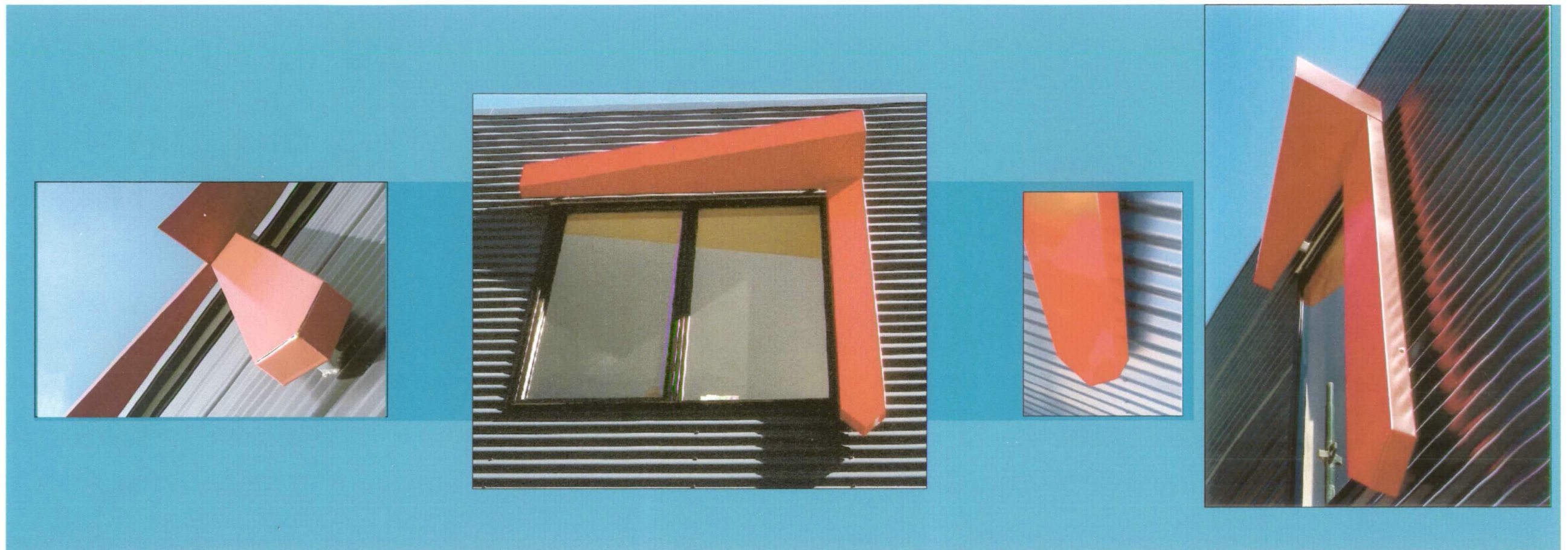
System One is the Latt-tile (pl.14). The modules have fundamental properties that allow its adaptation to an almost unlimited range of applications. As a tile it is able to be adapted to planar and curved or solid surface, as a lattice it is able to filter light and act as a wind break or provide visual screening. The two forms together provide many

¹⁰ Jane Pavitt, *Designing in the Digital Age in Millennium Architecture* Maggie Toy & Charles Jencks, Eds. Wiley-Academy, Bognor Regis, 1999 p.98

¹¹ Robin Evans *The projective Cast , Architecture and Its Three Geometries*, MIT Press MIT 2000 p354



PL. 15 System 2 Ceiling / roof plan



16 Volumetric Series 2004

adaptive functions, the modularity potential is unlimited, the scalability is also unlimited; all this in concert with modern materials and fabrication techniques.

System Two has been developed for a specific purpose, requiring different sets of criteria. The concept is not about a new form of roof / ceiling construction. The primary aim is to develop a multi layered geometric system of suspension points for facilitating the suspension in space of an experimental series of tri-dimensional drawing. The series of works being created within the three-dimensional virtual CAD space can be constructed and prototyped, as

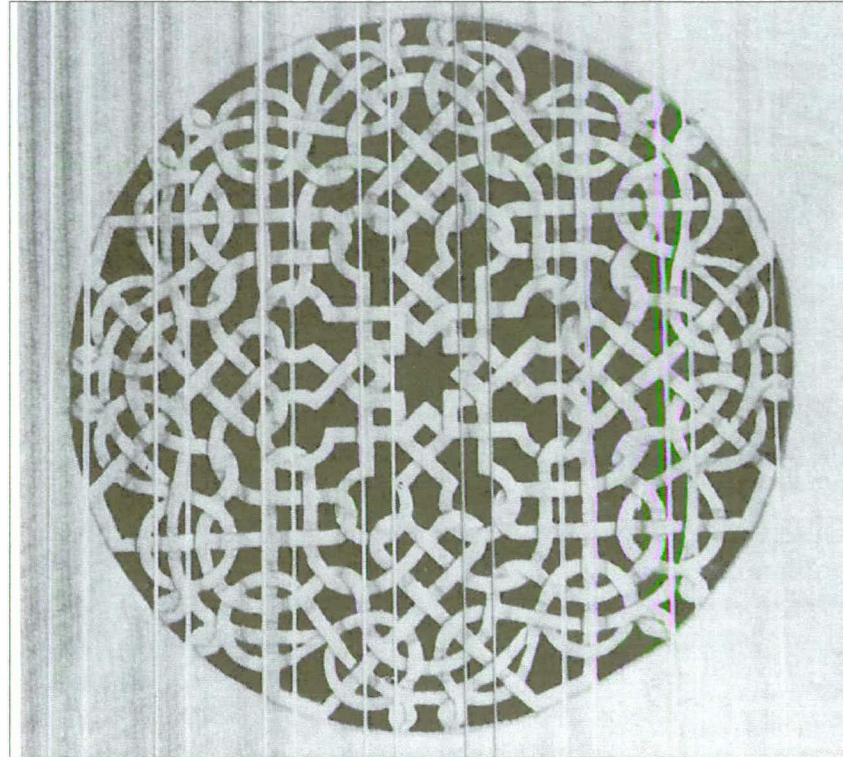
full sized models using the same co-ordinate systems within this new real grided space (pl.15).¹²

System Three - The Volumetric series - is a practical demonstration of the project's research outcomes. This work has its 'logic' based on the simple harmonic rules found in the recursive loop. The dimensions of structural components are chosen using the same sets of geometric rules. Similar principles are applied to the mounting system

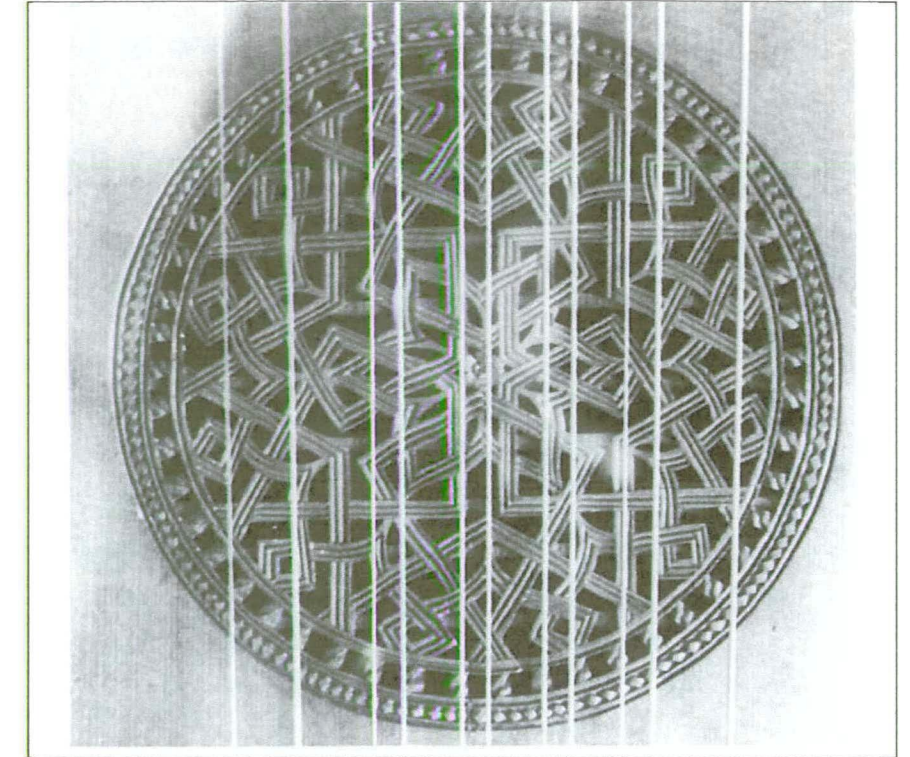
¹² This suspension system's geometry is an amalgamation of different symmetry systems; $\sqrt{2}$, $\sqrt{3}$ and $\sqrt{5}$ ratios are naturally occurring in this equilateral triangular grid. In the ceiling its symmetry is three-fold on the plane, and can be developed step by step to four-fold to five-fold symmetry. See Critchlow's chapter 5 for more information on symmetry transformations.

and the positioning of the modules in relation to other building elements. As a by-product of this form of design, the engineering of the principal cantilevering of the prismatic upper sections had a naturally occurring structural integrity¹³ (pl. 16).

¹³ The relationship of the cantilever dimension is proportional to the module's vertical element. When the structural loads were analysed it was found to be the ideal distribution of both the sheer and the compression forces, the three point suspension system as such was able to spread the oblique loads without any deformation of the Galvaspan steel material.



17 Leonardo da Vinci Lute rosette design using eight fold symmetry



Sixteenth century bass lute with six fold symmetry

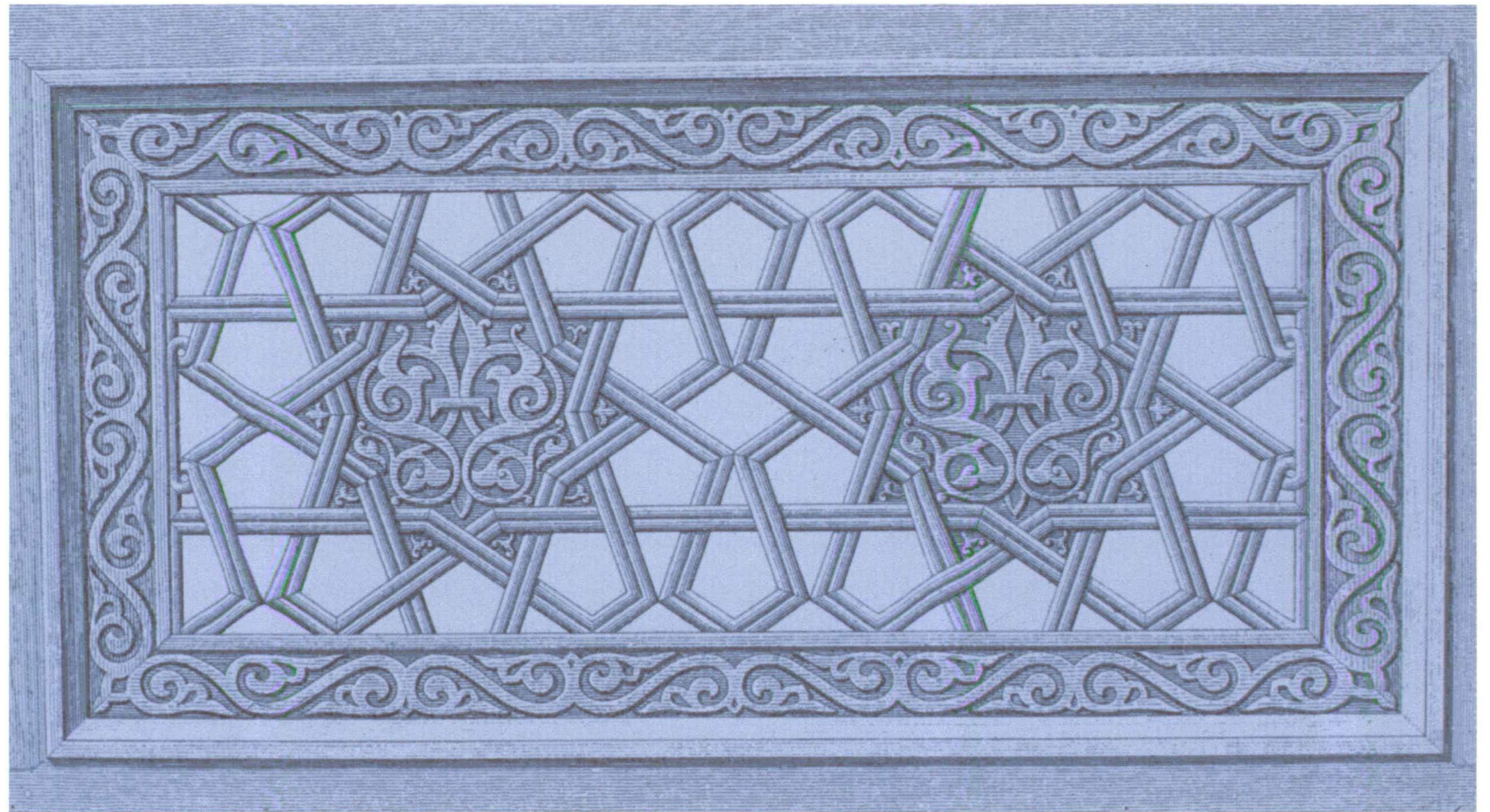
CHAPTER TWO: CONTEXT

As this project developed the context has bridged a number of areas of influence and research. In order to clarify the significant areas of interest and concern this chapter is made up of five topics of discussion. There have been several parallel investigations both in regard to artists working in my field in contemporary art practice and architects who employ conceptual tools, systematics and working strategies in areas of ornament, within both construction and façade. I have found parallels in the physical manifestation in new and old decorative systems.

Leading up to and during the Honours year before this

project began, I was involved professionally in the making of guitars as well as architectural design and building. During 1996 I was commissioned to repair the decorative sound-hole inlay of an early 17th century guitar. This work required research into the ornament used on instruments of the period. There are very few images or real instruments to study; most of the work was done through looking at paintings and drawings, in particular those of Northern European origin. It was my first real encounter with the work of Jan Vermeer. Also, whilst looking for instruments in drawings, I discovered the architectural tonal drawings of cathedrals by Pieter Saenredam; but it is the work of Albrecht Dürer that has been a significant influence.

This influence was concurrent with the study of lutes. My younger brother, a 'musician', was trying to persuade me to build him a lute and it was at this time that I first encountered the concept of interlace patterns in the form of lute rosettes (pl.17). Later research into tiling systems during the Honours year would bring with it the major and current interest in Islamic interlace geometry. But it has been the use of technical drawing and geometry that has been at the heart of this project. Even setting aside most of the painters that I had studied in this context, I am compelled to include Dürer and the subject of Geometry. The driving force behind my obsession with technical drawing has largely been the result of my professional life.



17a Wood work Panel

The trade of carpentry and joinery has provided many skills in the practical application of technical drawings. Early in my career my father¹⁴ passed on to me the skills and knowledge gained during his lifetime; his trade secrets, skills of traditional techniques, geometric surveying and joinery set out. This grounding has been combined with my own experience of many years designing and building. My obsessive attention to detail began when my father insisted that you have to know everything about your trade and the

trades of fellow craftsman. He instilled the essential need to be a lateral thinker when presented with difficult building problems. It was he who first taught me the fundamentals of Pythagoras' theorem and trigonometry; we would solve drawing problems together. He used to say when improvising on the piano... *"the best stuff is between the notes... - I play the cracks"*.

¹⁴Alan A Arnold (1913-75) began a carpentry trade in 1925. I also have heritage from my mother's father, Harold R Swann, Grand Master Mason, Northern Europe: family members have traced his family name Schwann back to 12th century Germany.



18 Melencolia I Albrecht Durer 1514

Geometry

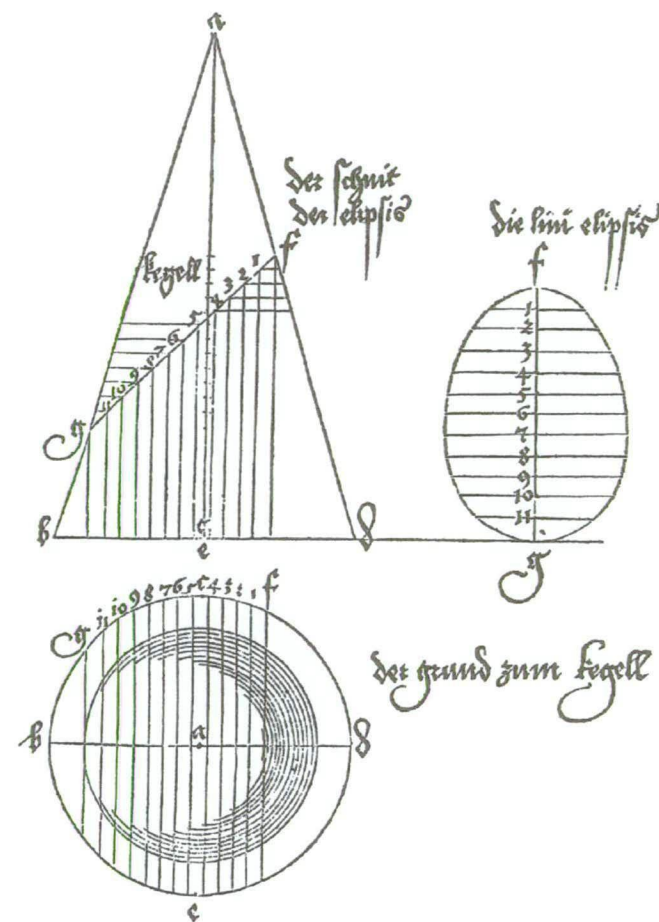
Although my father taught me the trade by example during my early school years, I still had to do an apprenticeship and it was during this apprenticeship that many hours were spent exploring methods of drawing. I learnt the use of compass and straight edge together with the setsquare, perspective drawing, polygons, the sectioning of solids and finding the true shapes of intersection projective development of surfaces. Also about the use of line on paper. All of the drawing techniques and methods have a legacy extending back to Albrecht Durer's treatise *Underweysung der messung (Instruction in Measurement*

with Compass and Ruler in Lines, Planes, and Solid Bodies), published by Dürer himself in Nuremberg in 1525.

It was my first encounter with an image of Dürer's engraving *Melencolia I*, 1514, (pl.18) during a lecture given by Jonathon Holmes in second year undergraduate Theory that caused a major rethink regarding my creative direction - moving from furniture design to painting as a major.

A fascination with Northern European art and Dürer¹⁵ was fostered by my acquisition, at the time, of Martin Kemp's book *The Science of Art, Optical themes in western art from Brunelleschi to Seurat*. Kemp states in his book:

¹⁵ Dürer: The master engravings *St Jerome in his study* and in particular 'Melencolia I', are replete with many layered and entwined levels of universal symbolism and meaning. The depiction in 'Melencolia I' of the tools of carpentry and geometry initially attracted my attention and provided insight into an artist's practice and it has been a central influence on the way I like to construct paintings. Of interest were the published and unpublished theories of Italian architects, mathematicians and artists. Among the most influential were Len Battista Alberti, Piero Della Francesca and Leonardo da Vinci. p78. Dürer also found answers to his many probing questions in the writings of classical authors such as Vitruvius and Euclid. His treatise written in German can be described as a handbook on geometry. Dürer's ideas were founded not just on the study of ancient and contemporary treatises but also on empirical research undertaken by the artist himself.



91. Method for determining oblique section of a cone, from Albrecht Dürer's *Underweysung der Messung*, Nuremberg, 1525.

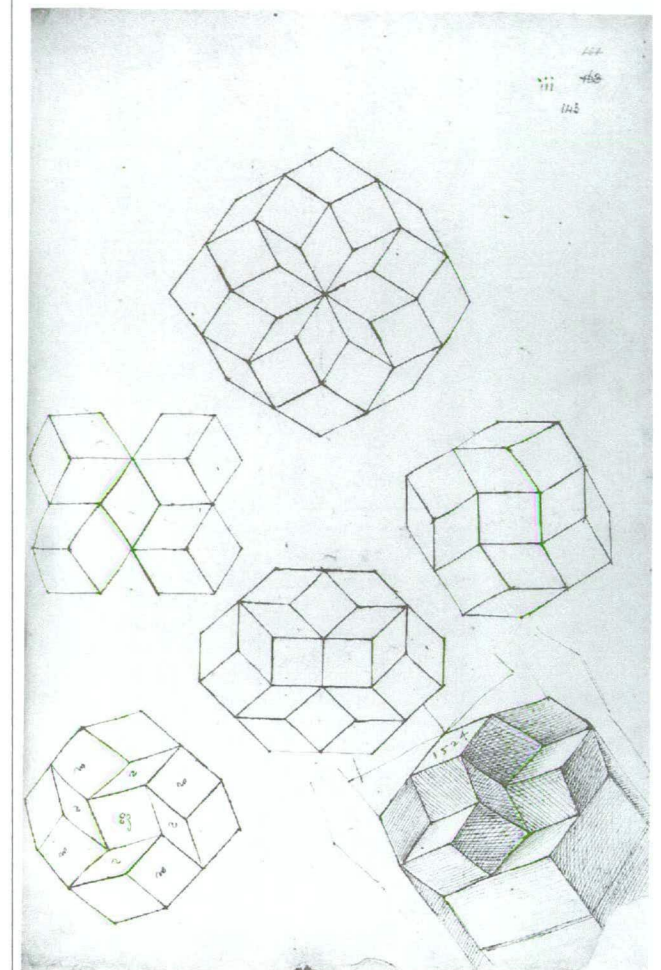
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Nuremberg was the centre of one of the most remarkable phases in Renaissance culture. It was a major centre for publishing, particularly in the fields of geography, astronomy, applied mathematics and music. It could boast metalworkers, armourers, and other craftsmen of high skill, to equal any in Europe. Nowhere were the sciences of practical mathematics and the new humanist learning more productively united. In the visual arts, its metalworkers stood supreme as a group, not only in the production of superbly decorative objects for the European aristocracy but also in the fabrication of scientific instruments, particularly the geometrical devices used in astronomy. Dürer himself came from a background in metalwork, his

father's profession, and the majority of the geometrical perspectivists who were to follow him practiced metalwork and/or instrument making.

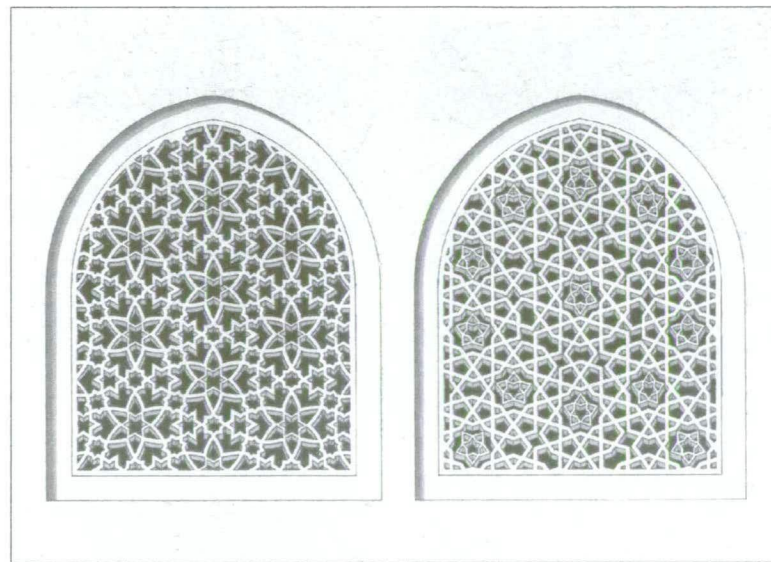
This treatise on geometry in the German vernacular was aimed at all those professions whose skills are underpinned by techniques of precise mensuration. It is divided into four books following a broadly Euclidean progression. The first is concerned with lines, most especially plane curves and varieties of spirals. It is in this section that Dürer made what was probably his most substantial contribution to mathematics, namely his analysis of conic sections (pl.19). Taking up the classical challenge of Apollonius's treatise on conics, he provides a practical way of obtaining sections

96. Albrecht Dürer, *Geometrical Designs*, 1524, London, British Library, MS Sloane 5229, fol. 142r.

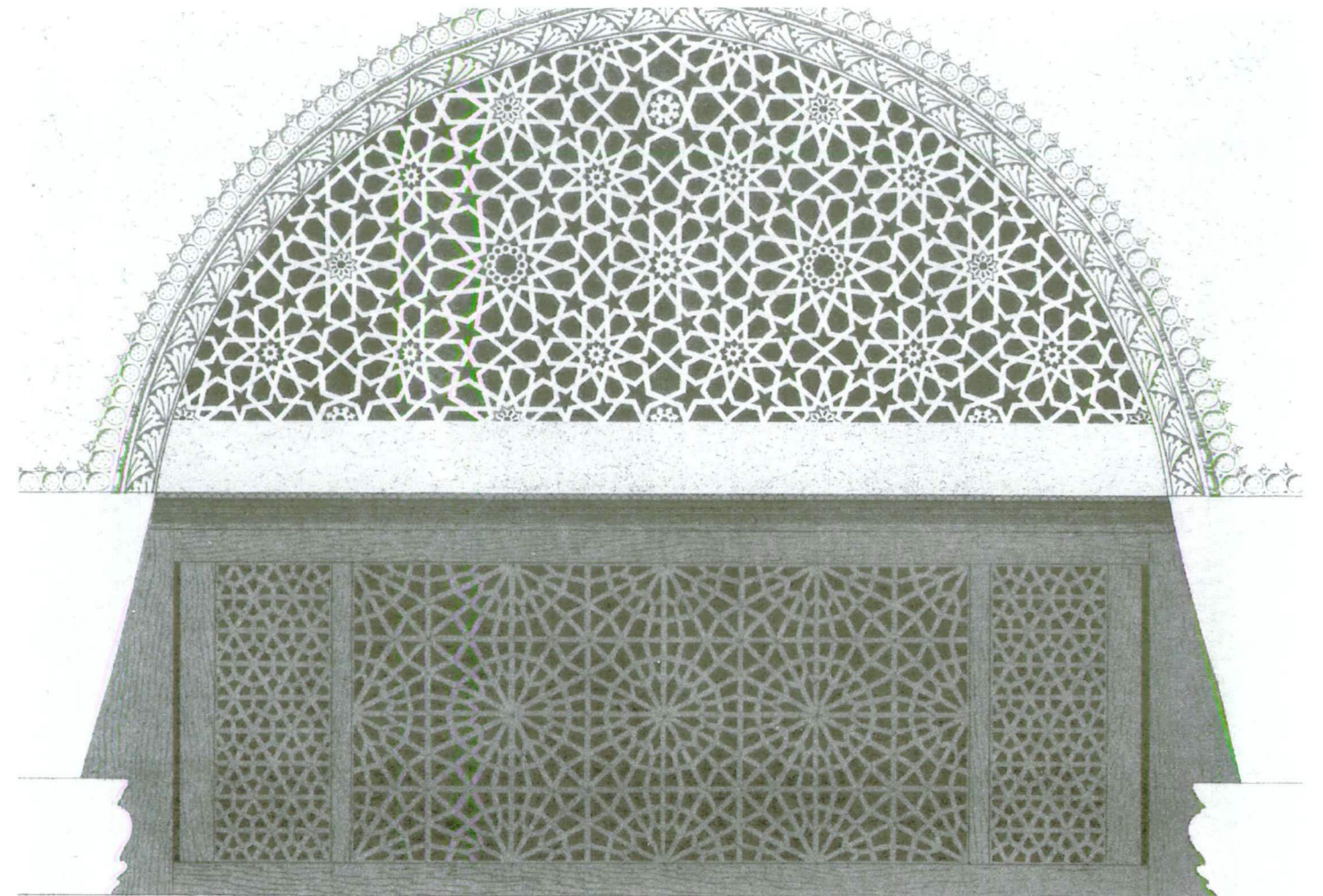


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of cones by what later became known as orthographic projection. The second book of the *Underweysung der messung* deals with the morphology of regular polygons, not only in the abstract terms of Euclid but also as applicable to decorative uses in tile patterns. The third book treats a variety of problems: the properties of certain solid bodies, such as pyramid, cylinders and architectural columns; the design of sundials and astronomical instruments; and the geometrical construction of letters, largely in the Piero-Pacioli manner. The final book is concerned with the properties of polyhedra (pl.20). With a characteristic sense of the concretely operational aspects of geometry, he illustrates a technique (also known to



21 Openwork Windows



21a Openwork Arch and Trellis

Leonardo) for displaying the regular and semi-regular solids in flattened forms so that they can be readily constructed from flat templates. This final book culminates in his analysis of geometrical perspective¹⁶.

Integral to apprenticeship training in carpentry, joinery and architectural drafting is the study of Euclidean geometry. Many hours are spent learning the practical application of trigonometry, the setting out of buildings being the prime use. But nearly all carpentry requires drawing; making

¹⁶ Martin Kemp *The Science of Art, Optical Themes in Western Art from Brunelleschi to Seurat*. Yale University Press New Haven 1990 p.55

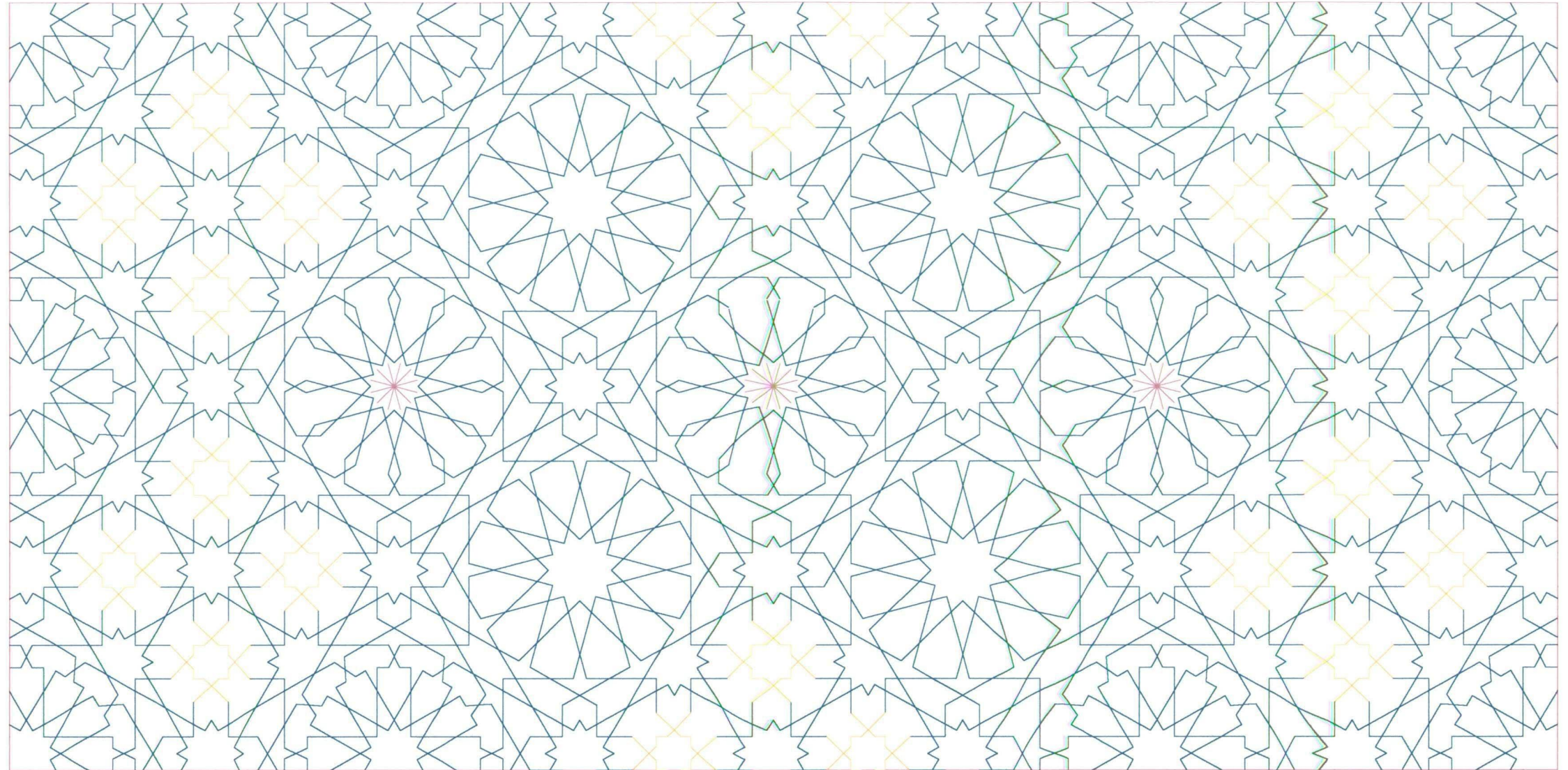
stairs and roof construction, and the use of templates and models. All of this former background work, research and study of geometric drawing, mathematics and scientific method has underpinned the current research project.

Islamic interlace

When the 12th Century Moorish craftsmen created the Alhambra, they made a building full of geometrically interwoven linear elements applied to almost every architectural medium and surface. Ceilings, wooden doors, and

openwork windows (pl.21) of the building exhibit interlace web commencing with the tiled revetments upon the walls and extending onto the ceilings in carved plaster and intricately fitted wooden ceiling decorations. These patterns were considered both as models of the heavens, and a more spiritually based metaphor of the cosmic web, encompassing the fusion of rhythms, harmonic, and mirrored symmetric sequencing.

The revetment interlace from the Hall of the Ambassadors (pl.22) has been the focus of the majority of my work on interlace drawing. It has a number of unique characteristics, one being the oblique over-lapping rhomboid pathways



22 Centre line constructive geometric line for revetment interlace design, variation of previous line drawings

between cells; many variations of the more basic versions are used throughout the Alhambra in the tiled revetments, or ‘Eltebas’¹⁷, and are still being created today in Morocco.

When drawing the map of interlace pathways, if a large number of core cells is involved, the complexity of the visual play of lines that occurs continually brings to mind associations with spider webs.

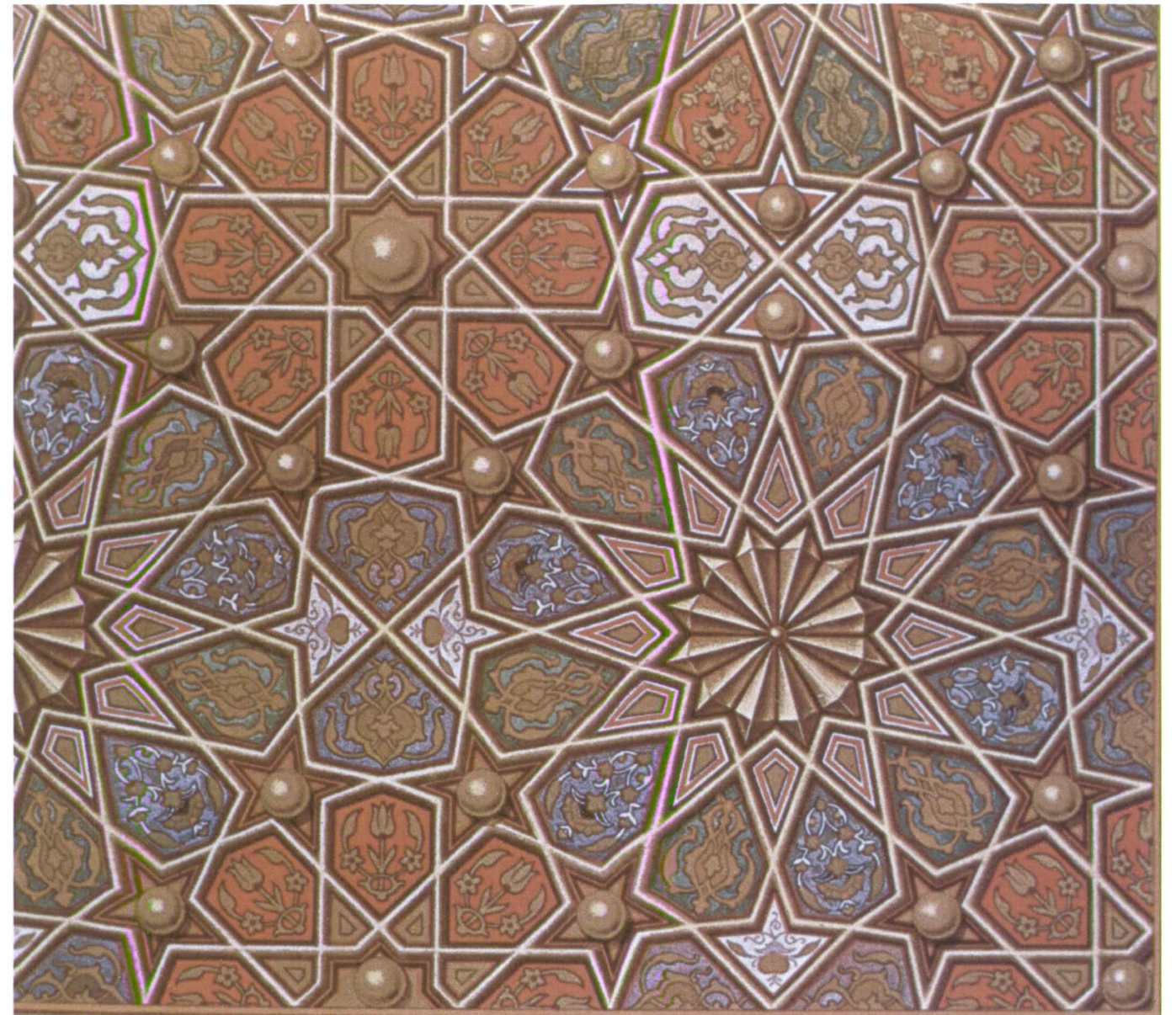
A spider’s web is another example of a complex pattern formed by a single agent. The spider traces a complicated

path in time as it spins: the pattern of the resulting web in space is a record of the spider’s path. We can see here that complexity is seen not at the level of an individual, be it animal, plant or mineral, but in the larger picture, which may be an aggregate view over time or space. In the case of the spider’s web we can see a very clear pattern; in the case of the ball of wool there is no obvious pattern at all. Patterns, intertwined paths, structures of all kinds, are hallmarks of complexity... You do not need many cats for chaos, either, as a kitten with a ball of wool will soon demonstrate! As the kitten chases the ball of wool around the house it unravels, leaving chairs, tables, just about everything, tied together. Each time the ball hits an obstacle

*it bounces off at an odd angle, since is not a perfect sphere. Unless we can find an end to the wool, we have no idea, where the path started or stopped. Here we have one agent, following a complicated path, going round and round the same area, along slightly different paths each time. We might call this the ‘iterative approach’ to complexity; the repetition of simple acts again and again*¹⁸.

¹⁷ Revetment – Eltebas is the Arabic word for revetment and means ambiguity or self-veiling.

¹⁸ Terry Bossomaier and David Green *Patterns in the Sand, Computers, Complexity and Life*, Allen & Unwin, NSW Aust. 1998 p.6



23 Detail: Polychromatic decorative painted ceiling, Morocco

A fundamental principle is that if a pathway or any shaped single element is reflected between two mirrored surfaces with the mirroring axis set at significant angles and positions, each new element will take on new values in the patterns of reflection¹⁹. When one ‘walks’ the pathway, following the principles of a quasi-random mirroring of the path, taking steps in linear leaps, over and under and enmeshed in the elements, one is able to experience the rhythm and sense of completeness. This is one of the most

¹⁹ Keith Critchlow *Islamic Patterns An Analytical and Cosmological Approach*, Thames and Hudson 1976 p.74

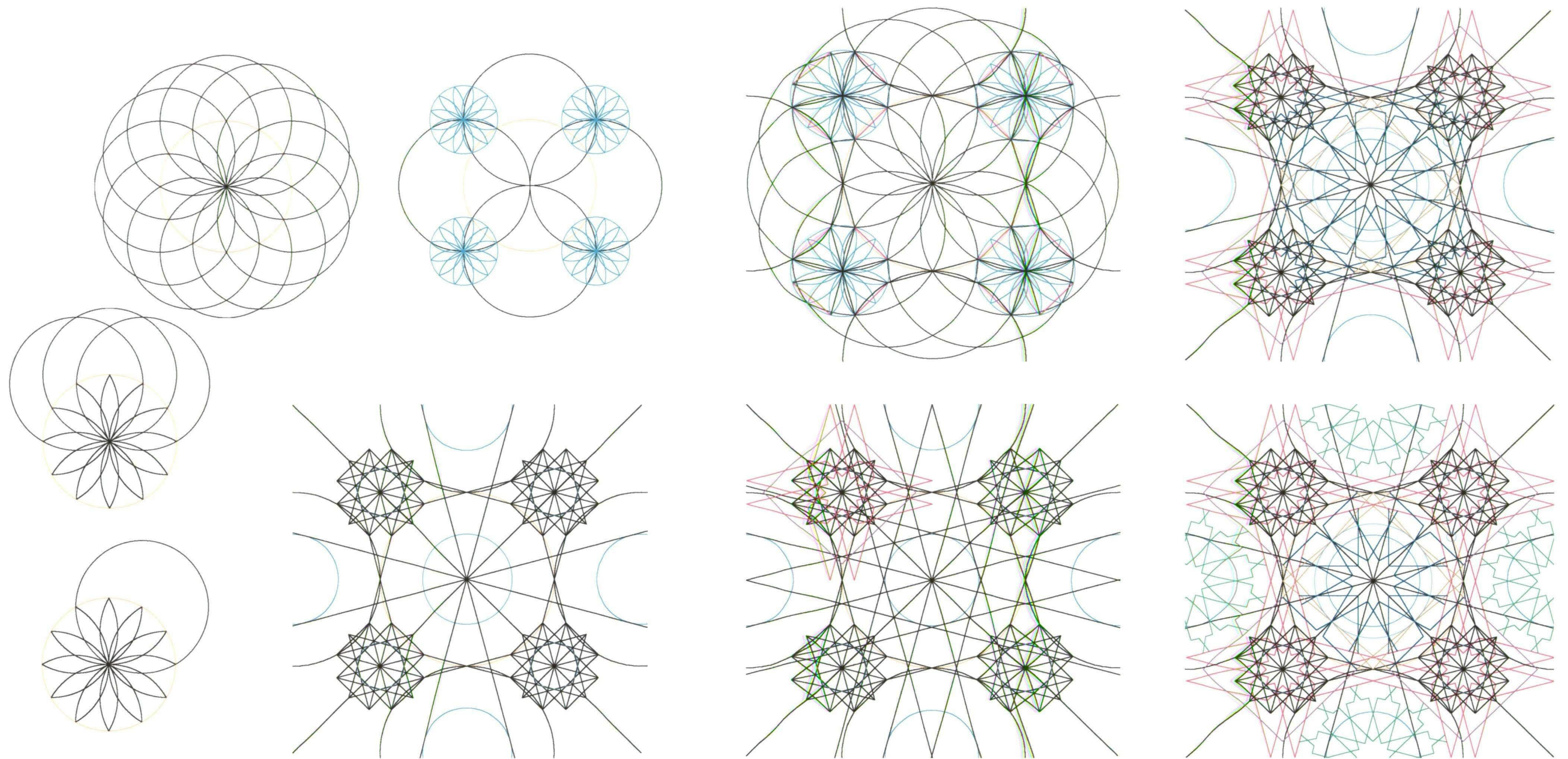
attractive aspects or properties within the interlace designs in the Alhambra.

Drawing the Cosmic web: It's been as difficult as herding cats²⁰

During earlier work I had come across a Dover Publication, a reprint of Jules Bourgoïn's *Les Elements de l'Art Arabe: Le trait des interlaces*, (Firmin–Didot et C^{ie}, Paris, 1879): a facsimile book of plates of Bourgoïn's geometric construction pattern drawings of designs created by Arabic architects, decorators and craftsmen. All the seventeen

²⁰ Terry Bossomaier and David Green *Patterns in the Sand, Computers, Complexity and Life*, Allen & Unwin, NSW Aust. 1998 p.6

known symmetry groups have been proven to exist within the decorative tilings in the Alhambra. The various types of decorative systems of polychromatic ceramic tilings in the Alhambra together with Bourgoïn's drawings of interlace pattern have provided a rich source of influence. Strangely this volume of 190 drawing plates has alone been more influential and useful as a resource than the actual tiled panels or painted ceilings. All the drawings in this volume form the geometric foundations underpinning the Islamic interlace patterns. The exception is the actual wooden ceilings, openwork windows and doors (pl.23). Woven linear elements are applied to almost every architectural medium, and surface, ceiling, wooden doors and panelling.



24 Division of circle with compass and straight edge geometric projection shown in stages of development

Ornament is within the building fabric where line/structure are one.

A major feature of these interlaced designs is that they are all built upon the systematic division of the circle: a vast range of variation and derivation exists. All constructed, astoundingly, with just a few rudimentary instruments such as the straight edge and dividers (pl.24). Although one might think this equipment rather inadequate as lacking in measuring and number, it is no obstacle, for upon investigation it is possible to construct geometric polygons

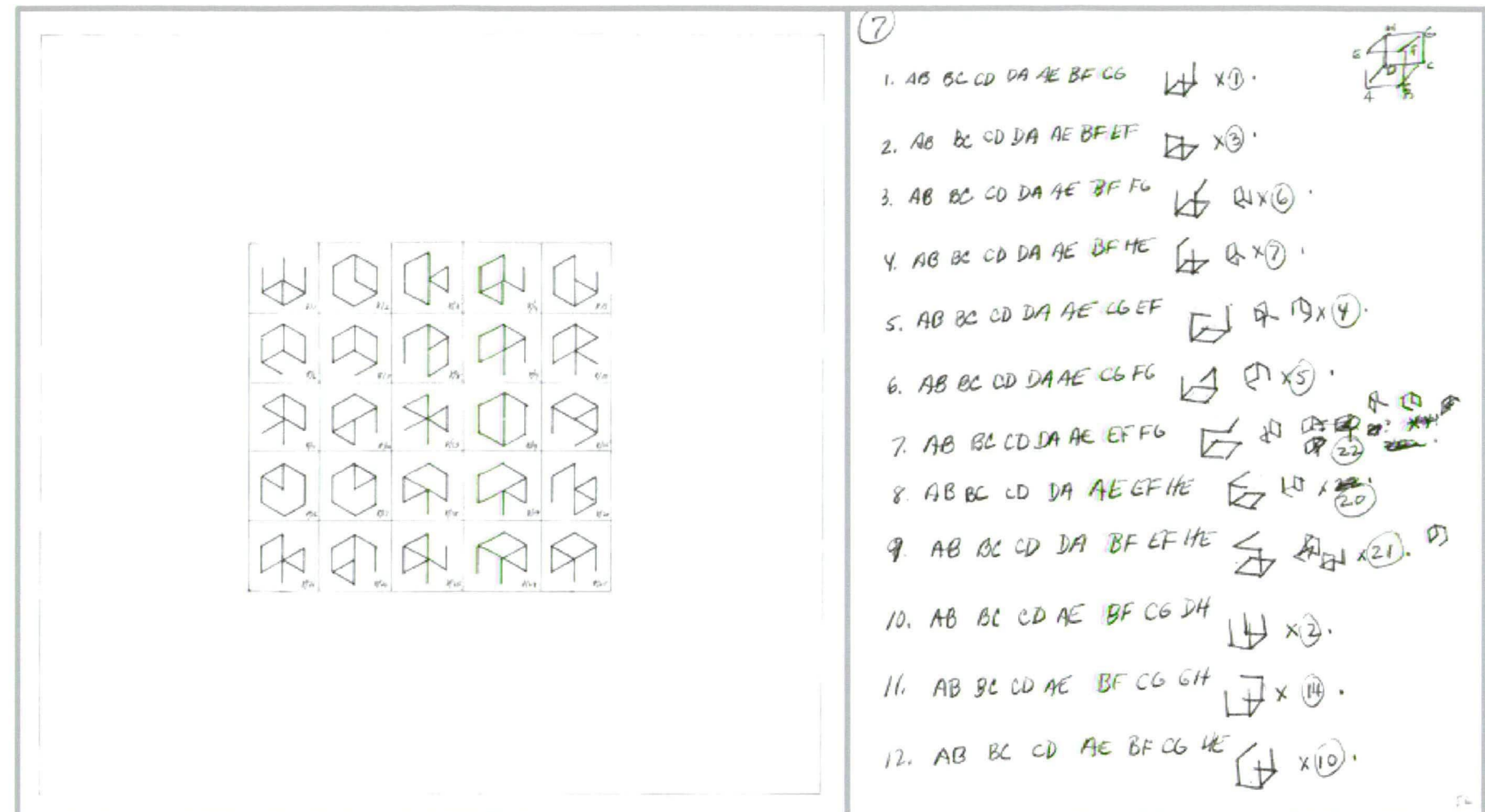
and angles with these two instruments alone. But as Keith Critchlow states...

The triangle, the square, and even the pentagon are relatively simple to construct. However, in the case of a seven-sided and a nine-sided polygon the methods of construction are somewhat less obvious. Hence the mystery associated with them in the mind of the ancients, this was directly related to the fact that there is no known method of drawing them with absolute precision using only a straight edge and compasses. However, certain working approximations are known, and when it comes to practical application by a craftsman or the making of a tile of such

shape, the approximations are valid inasmuch as they may be accurate to within a few 100ths of an inch²¹.

They accomplish these approximations in practice, by using a combination of techniques incorporating an intuitive trial and error system to aid in the adaptation to architectural surfaces.

²¹ Keith Critchlow *Islamic Patterns, An Analytical and Cosmological Approach*, Thames and Hudson 1976. Most comprehensive definitions of methods for constructing polygons with compass and straight edge only. pp166 - 171



25 Variations on incomplete cubes 1974 with hand drawn diagram

ARTISTS: Systems and Obsession

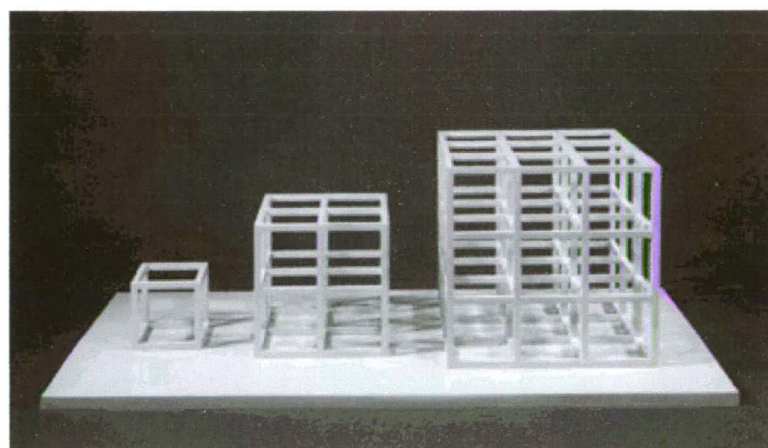
The words 'methods' and 'process' go with words such as 'obsession' and 'repetition'. Simple algorithmic sets of acts, when placed in relationship to each other and to sets of rules, grids or other conditions (the hallmarks of complexity theory), can produce seemingly complex, often extremely complex, visual results.

Looking at an artist such as Sol LeWitt it is not only the obsessive process he employs or the diversity of his interests or his methodology or the breadth and scope of his work as it spans many years and different media that

interests me, it is, particularly, the architectural dimension to his work. Sol LeWitt's work strategies resonate with my own interests and research.

Also it has been the serialisation and the multiplication in LeWitt's works such as the *Variations of Incomplete Open Cubes 1974*, in which he assembles one hundred and twenty-two variations on the linear structure of a cube. LeWitt has serialised works on the cube since the late 1960's. The works are still being exhibited and made to his instructions for gallery installations, worldwide.

In this work he employs a single idea. It is the simple idea of working out every possible combination of the configuration of the elements that make up a cube. He commences with a drawing of the fewest elements needed to simulate or imply a cube. It requires three elements in isometric view. LeWitt's hand drawn diagram is the actual figuring out or the attempts at analysing and noting all possible permutations of elements needed through to a maximum number of sides, which is eleven, until the cube is complete (pl.25). He is dogged in his unrelenting pursuit of variations on an idea.



25a 1 2 3 Sol LeWitt 1978



25b Open Cube Sol LeWitt 1978

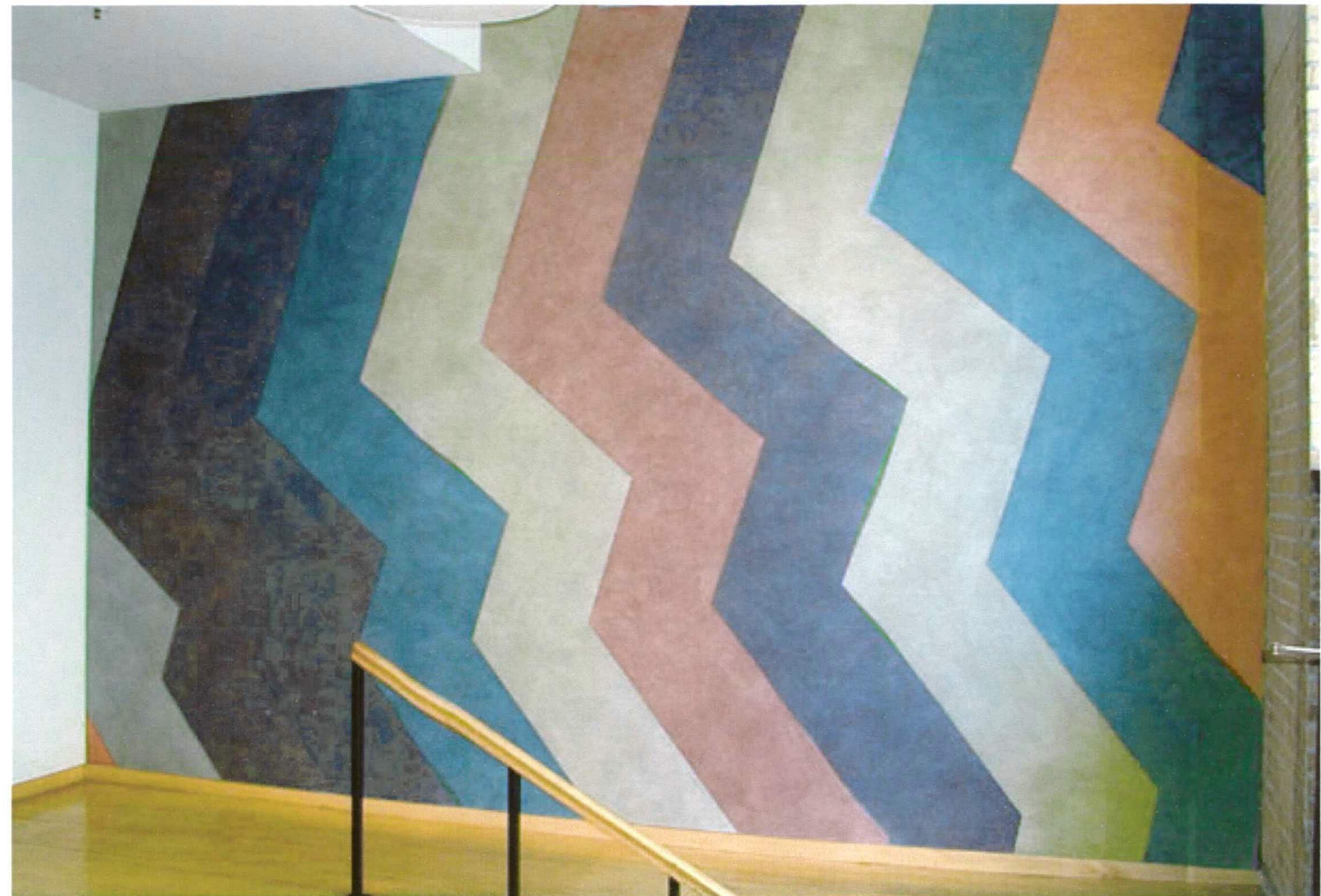
The white linear frameworks of the cubes are set against a black background which accentuates the spatial play and the visual oscillation within the architectural space where implied surface drifts to implied plan; to implied volume where form and shadow, through line and shape, fall in and out of pattern. The stacks when viewed from various positions defy the sense of a concrete definition of space by the folding of three-dimensionality to two-dimensionality and back again. The multiple stacks of cubes allow one to see many views of the single cube at once, shifted from the unity of the base cube, isomorphically.

*LeWitt's grids are ubiquitous. As structures they hang on the wall, fit into a corner, or "hold the floor." The wall pieces can be flat, with only the shallow depth of the members defined by shadows, or they can project to the depth of a cubic unit and, depending on the number of units, set kinetic passage in motion as the viewer approaches. Shadows also play a role, creating diagonal lines in this three-dimensional crosshatching.*²²

²² Alicia Legg, Catalogue Introduction, *Sol LeWitt*, MOMA, New York, 1978 p.9

The way I read this visual game is through the construction of the not-seen harmonic boundaries. By this I mean the natural perspective generated by viewing LeWitt's cubes to accentuate the $\sqrt{2}$ harmonic rhythm. The diagonals of the cubes, although not present in reality, are the $\sqrt{2}$ dimension. Lucy R Lippard writing in the MOMA 1978 catalogue says ...

While LeWitt does not discover by making – the traditional artist's method – he still discovers by doing. All of his ideas, he emphasises, are two-dimensional in origin. With



26 Sol LeWitt Wall Drawing 1980

*his pen and notebooks he enjoys “drawing out” the evolution of simple ideas...*²³

LeWitt has periodically completed booklets of drawings as serial pieces with descriptive titles which describe the algorithm that is contained. A title such as *Geometric Figures within Geometric Figures, 1976* is a booklet of diagrams showing all possible combinations in thirty six squares, circles, squares triangles, rectangles, trapezoids,

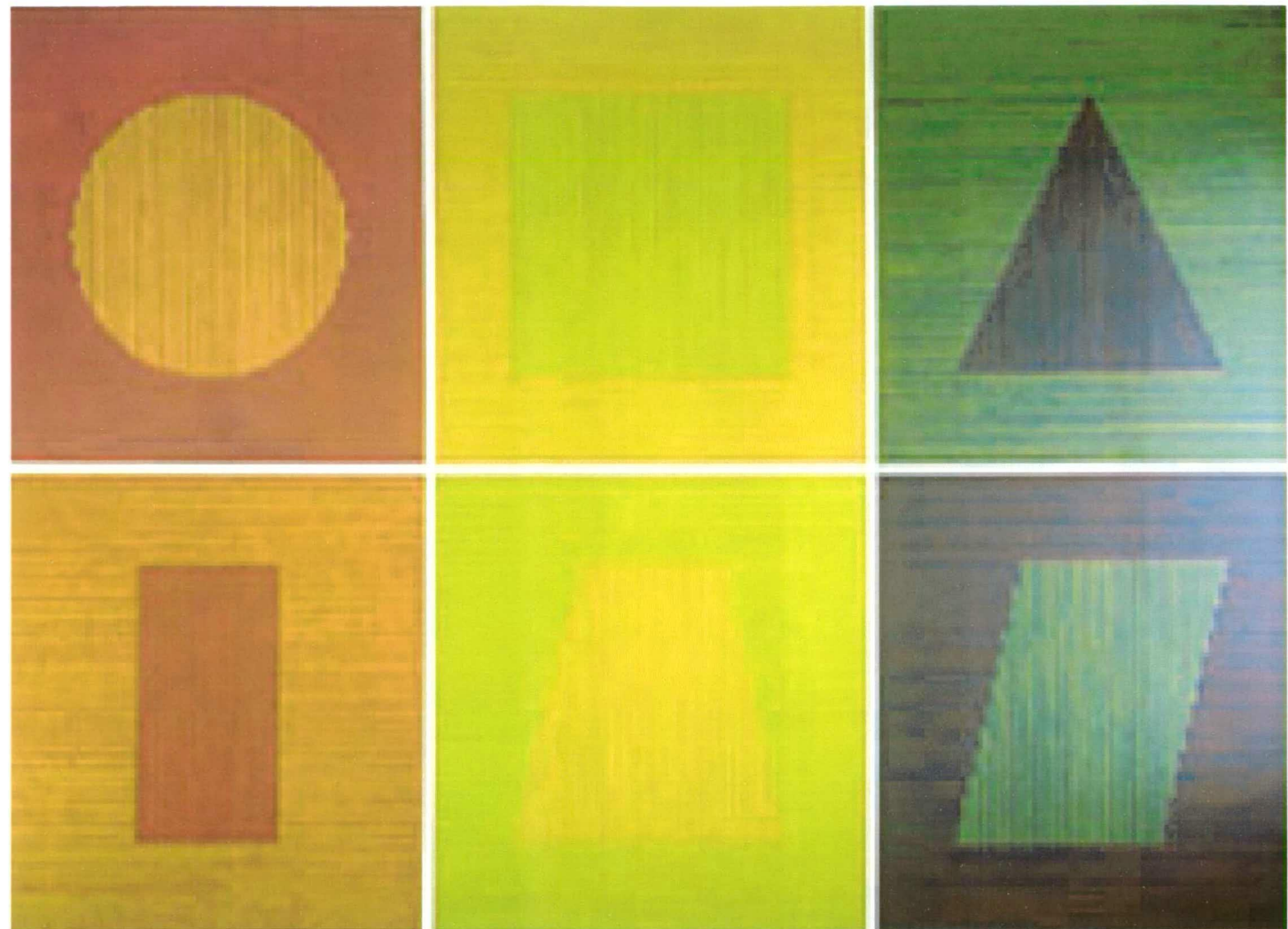
²³ Lucy R Lippard, *The Structures, The Structures and the Wall drawings, The Structures and the Wall Drawings and the Books*, in MOMA Catalogue *Sol LeWitt*, New York, 1978 p.23

and parallelograms within circles, and squares etc. Here he has systematically drawn each and, at the end of the book, has combined all the figures within one diagram. He has done similar books using lines in all sorts of different combinations and sets, with defining descriptive instructions as titles.

This form of serialised concept is carried through to two-dimensional wall drawing (pl.26) where he has given instructions in written form to a draftsman. Instructions such as *draw lines at 45 ° from one corner at a certain length a certain distance apart, from floor level or some architectural point or junction of some architectural element*. He uses the shapes of doors, beams, and fixtures

to generate the works' dynamics. Coloured lines are all juxtaposed using the wall as his sheet of paper and responding to its surroundings and direct engagement with the viewer. A purchaser of a wall drawing receives a photograph of the completed piece and a certificate, which combined with the page of instruction gives the person the right to install the work on any wall they choose.

LeWitt's wall drawings are reduced to the 'absolute' and addressed to our immediate perception rather than to our conventional responses. They preserve the contemplative and rationalising functions that were always the special



26a Sol LeWitt Wall Drawing # 340 1980

privilege of drawing, asserting them as a real part of the world. What interests LeWitt is the multiplicity of things, and his systems continue to multiply new ideas. He is interested in maintaining the integrity of the completed sequence... LeWitt's wall drawing retains the crisp, hard, flat-surfaced quality of a dry medium and of a line drawn with a hard medium and of a line drawn with a hard tool and a straight edge²⁴.

²⁴ Bernice Rose essay: *Sol LeWitt and Drawing*, in MOMA catalogue *Sol LeWitt*, New York 1978 p.41

In the same essay Bernice Rose draws on comments by John Chandler published in *Art International*, September 1968...

The use and disuse of systems in intellectual history was outlined by John Chandler in a discussion of LeWitt:

The current concern of artists with "systems" recalls the rejection of systems by the eighteenth-century philosophes. The seventeenth-century philosophers, following the model of Euclid's Elements, constructed elaborate systems, long chains of deductive reasoning where every link depended on all those which preceded it and upon which all further links depended. The eighteenth century, following the lead of Newton and natural philosophy, rejected this kind of

deduction and rejected a priori systems. Rather than beginning with principles and arriving at particulars, the process was reversed. Knowledge became more elastic, open-ended and concrete. Since then, attempts to make systems have been negligible, and when they have been formulated, they have been useless. The formulator of a system of aesthetics has nothing to say to working artists because he has not observed the relevant phenomena - in this case, contemporary works of art. Nevertheless, some of the most beautiful of human productions have been these philosophical systems. What is more beautiful than the systems of Aquinas, Spinoza, Hobbes and Descartes?... Every part in its appropriate place, deduced from those

prior and antecedent to those that follow, the whole being an attempt to reduce the apparent variety to unity. Even their uselessness enhances their aesthetic quality, just as a ruined Gothic cathedral is perhaps more a work of art now than it was when it was functional. Although systems are useless for philosophy and science, their inherent adaptability to art must now be evident. It is perhaps in art that systems have found their proper domain. Not all art should be systematic, but all systems are art... Systems have other attractions, too. A simple system may yield a complex field. Systems may seem logical but can be used to confound logic when extended to absurdity. The rule

*dominated anti-aesthetic system that generates its own style is not new with LeWitt; it is a tradition of modern art.*²⁵

Bernice Rose also draws on observations made by Lawrence Alloway published in *Artforum*, New York, 1975...

In an article on LeWitt, Lawrence Alloway first noted the connection between LeWitt's work and the historical concept of disegno (although LeWitt apparently knew nothing of the concept)... Disegno – the word embraces both design and drawing – in this sense is the same as

²⁵ *ibid*, pp33-34

drawing with “ invention”. That is, drawing is equated with the “engendering of” the idea or the form of things before and, even independent of, any concrete realization. This definition of disegno, in its pure form “idea” alone, is called disegno interno. It was thought of as the idea that exists in the mind of the creator prior to the act of creation. God the father was its source; the idea was present in man's mind as a spark of the divine mind. A second meaning of disegno refers to the work itself. Both concepts have coexisted since the sixteenth century, although “ideas” have seldom been wholly divorced from their concrete realizations. For the sixteenth century, speculation about the dual nature of drawing produced a

*rationale about the relationship between art and nature. If disegno was the generating source of artistic representation, the human intellect “by virtue of its participation in God’s idea – rational ability and similarity to the divine mind as such” proceeded in the same way in producing a work of art as nature did in producing reality. This led to the conclusion that there was “an objective correspondence between the artists’ products and those of nature.”*²⁶

²⁶ ibid pp.38-39

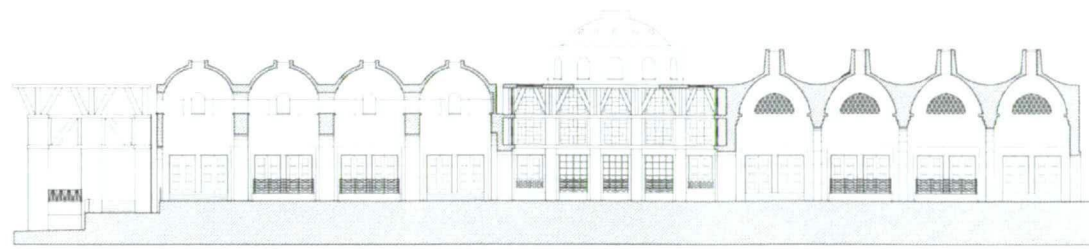
‘Conceptual’ is how Le Witt refers to his work. To him idea is paramount, that all parameters of the work must be understood and that the artist has done all the thinking in advance. He wrote, *the execution is a perfunctory affair*. He also states, *The idea becomes the machine that makes the art.*²⁷

Aristotle said: *Pleasure perfects activity not as an inherent habit but as a kind of supervenient end.*²⁸

²⁷ ibid p.9

²⁸ This is something I have remembered from early readings of Aristotle from the age of 12

My interest in componentisation and systemisation of serial methods is connected to the essential pleasure of both the drawing and the making process.



27a Michael Graves elevational section drawing Hyatt regency Taba Heights Egypt 2003



27 Michael Graves Plocek House 1982

ARCHITECTS AND ORNAMENT

I have been designing residential buildings since my early teens. During 1984 I was working on the design of two houses: one at Oceania Drive, Howrah and a second at Pengana Place, Blackmans Bay, both in Tasmania. While undertaking the initial research for these designs at the Architecture Library, University of Tasmania, I encountered the mid-year volume of the architectural journal *Architectural Record*, which was solely devoted to avant-garde house design in the USA. This was my first encounter with the work of Michael Graves and Peter Eisenman whose careers I have followed to the present

time. With Graves it is his use of colour, form and façade that interests me; with Eisenman it is his use of fragmentation, spatial disjuncture and the computer.

Graves' early work with houses has certain repeated characteristics used in developing a language of allusion and metaphor - the use of coloured forms, solid sections of walls in relief and overlayed on façade, structural-blocks used as 'pure metaphor'. For Graves the grid is also an important ingredient in his work, but for Graves it doesn't have the utilitarian associations like Le Corbusier's use of the grid. Graves uses architecture's constructive devices as a vehicle for the moving and expression of architectural

meaning into the realm of 'pure visibility'. By this I mean he takes a component form or element of a façade, even if quoting a historical form, and exaggerates it by extruding its form forward of the building surface in relief. An example of this is the Plocek House where Graves has used subtle pastel hues to define and separate the elements (pl.27). The system he employs gives the Plocek House a sense of structural support or buttress that speaks of a fortress of privacy.

Graves treats the elevation drawing as though it is stood up full size from the ground to form the wall, turns it into a three dimensional object by extruding elements out from the two-dimensional to the three. He uses the construction system of a house as a vehicle for this type of treatment. He uses architectural elements, buttress-like forms, window pelmets and lintels, architraves as devices to extrude the surface, highlighting them with colour to produce semantically loaded elements. He is interested in how such structures work perceptually as the product of conflicts and tensions in the psyche of the individual.

He demonstrates the process by which meanings are generated using a language that depends on oppositions, fragmentation and visual pun.²⁹ Graves creates paintings himself, using surfaces and façades of his architectural creations: he uses their 'shock effect' to undermine expected hierarchies. Graves is able to treat structure as 'idea'. The artwork and architecture of Michael Graves is of importance to me particularly regarding his involvement with decorative façade.

²⁹ Alan Colquhoun, *Architectural Monograph 5, Michael Graves*, Academy Editions, London 1979 p.10

Graves' paintings, like his plans, are built from collages of fragments. He works with edges that to me speak of the cube and its division. He plays with pictorial elements shifting planes forward and back in the manner of a cubist painter. Graves is interesting because he develops systems of ornament using architectural elements as he would blocks of colour on a painting. Within his murals one sees painted architectural elements in two-dimensions. He uses an architectural element such as a cornice or classical bolection moulding, extrudes it into an element, often scaling it up in size, which he then uses for such things as a handrail or a door lintel or simply a fragment on a wall.

They sometimes appear as projections into three-dimensional space from his wall drawings or paintings.

As Alan Colquhoun states,..

In his role he is called upon not only to decide matters of decorum; like the modern painter, he is expected to say something 'new', to propound a philosophy. No doubt this applies only to a minority of clients (and even these are probably often puzzled at the results); but their very existence explains how an architect as intensively 'private' as Michael Graves can insert himself into the institutionalised framework of society despite the absence of a clearly defined 'market'.

*Through the utilisation of his client-based work for a means of canvas, Graves exploits a technological condition that is very favourable to his architecture. A system of construction, (known in the USA) the balloon frame- a system of construction whose lightness and adaptability gives the designer great freedom; he can flaunt structural conventions, blur the distinctions between what is real and what is virtual, and provide a possibly inconceivable fusion of structure and ornament.*³⁰

³⁰ ibid p.8

During early research on my project I came across this statement about Graves' work, also by Alan Colquhoun, that had a profound effect on my design thought processes at the time. It was during the formulation of systems of linear elements.

Within Graves' work the most persistent idea is that of the open frame defining a continuous space partially interrupted by planes and solids. Not only are horizontal spaces continuous but vertical penetrations occur at crucial points to create three-dimensional continuity. Through this space the frame is threaded, creating dialectic between a rational a 'priori' order and a circumstantial, sensuous and complex plastic order. This is in essence the 'free plan' of

*Le Corbusier, but developed with greater complexity in a repetition, transformation and inter-weaving of formal themes reminiscent of musical structure. Tensions develop round the periphery of the building and there is maximum exploitation, by means of layered screenings and shallow recessions, of the plane of the façade - the intense moment of transition between the 'profane' world outside the house, and the 'sacred' world inside.*³¹

This paragraph gave me quite a jolt; in particular when I was trying to resolve the extrapolation of two-dimensional

³¹ ibid p.13

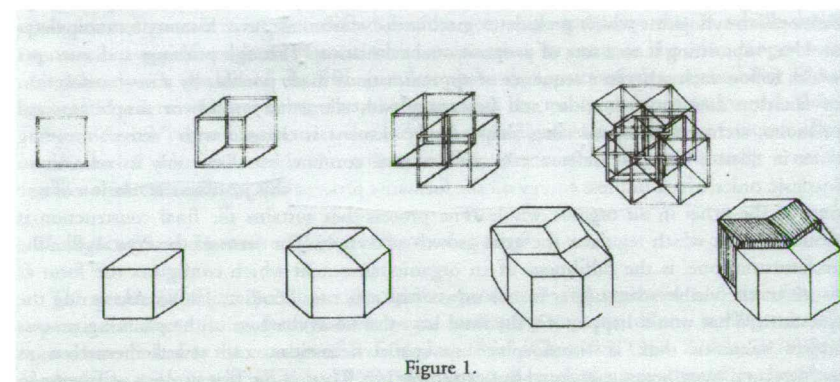
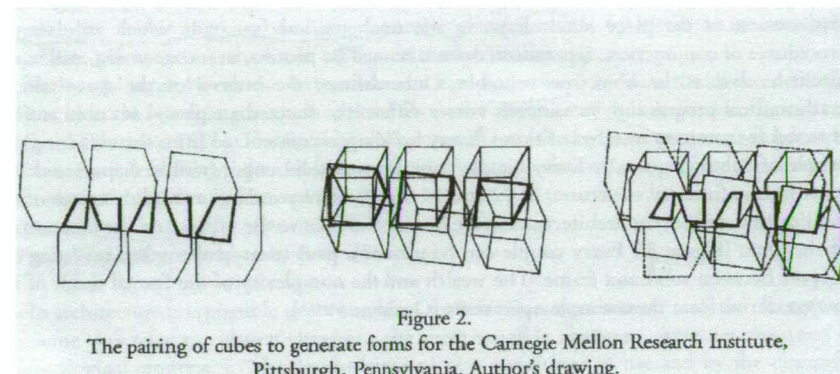
bounded line elements within interlace pattern drawings into three-dimensional arrays of spatial lattice structures. It has helped solve issues regarding the placement of the Volumetric Series of work, introducing a functionary role for architectural ornament as structural elements; the role objects that have been modelled in the virtual world of the CAD drawing environment can play.

In contrast to Graves, Peter Eisenman's work diverges towards a syntactic language of exclusion. The complexities can deny reading and repel. In the mid-sixties they worked together, sharing the same influences and both sought to

create a new architectural language out of the modern movement. With Eisenman the semantic dimension is conceptual and mathematical; with Graves it is sensuous and metaphysical.³²

About Peter Eisenman, Adriana Rossi wrote: *Every element is charged with "active" meaning since it doesn't have any reference or architectural content, but lives only in relation to intrinsic order which impress energy on the formative process.*³³ *This justifies the relation of one part to the other in an organic whole. The process that sustains the final construction is similar to that which regulates the axial*

³² ibid p.9



28 Eisenman, Carnegie Mellon Research Institute. Cincinnati 1988
spatial isomorphism, of cubeforms drawn by Adriana Rossi

growth of crystals. The form of the crystal, like the architectural one, is the fulfilment of an organic movement, which configures the form as much in the visible structure as in the substantial structure.³⁴

Peter Eisenman manipulates an idea, submitting it to a sort of propositional calculation. Through probing and attempts which follow each other in a sequence of approximations made possible by a new conception of notation and

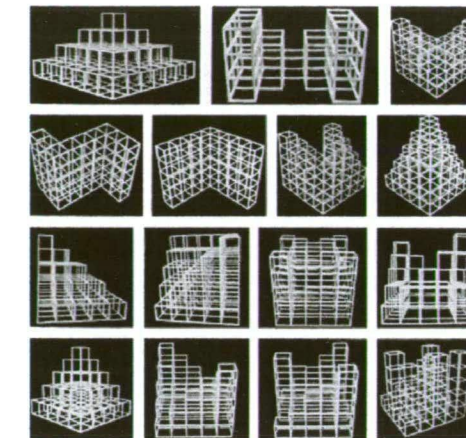
³³ Adriana Rossi, *Nexus Network Journal*, Florence 2000 Vol 1 p.66

³⁴ Republished in *Nexus Network Journal* Vol 1, 2000 by gracious permission of World Scientific Publishing, [Zodiac, 1969]

representation, and beginning with elementary solids or simple internal relations, architectural space takes shape³⁵.

Peter Eisenman is one of the first architects to have built a practice on the basis of computer generated buildings. The plan for the Carnegie Mellon Research Institute (CMRI) Pittsburgh Pennsylvania 1987-88 (pl.28) is an emblematic example of Eisenman's beginnings with a computer driven creative logic. The fundamental aspects of this architectonic elaboration are related to the use of CAD and the geometric Boolean cube, a tri-dimensional cube that can be either solid or transparent frames. Eisenman manipulates an idea,

³⁵ Adriana Rossi, *Nexus Network Journal*, Florence 2000 Vol 1 p.67



28b Sol Lewitt cubes (1966)



28a Wexner Centre of Visual Arts Ohio State Un.
Eisenman 1989

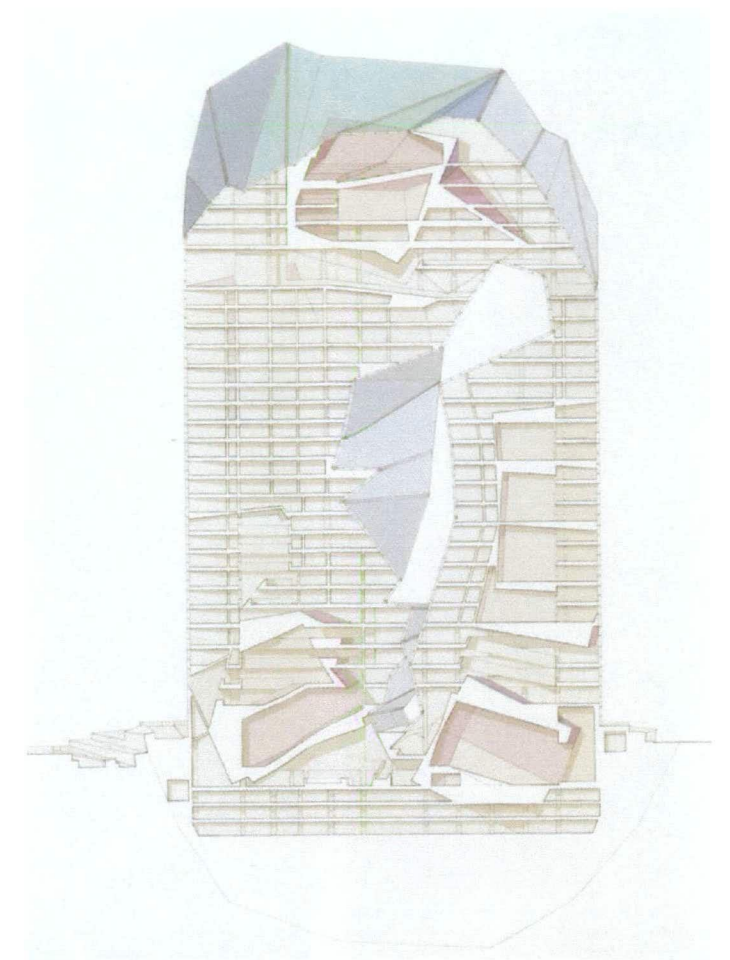
submitting it to a sort of propositional calculation. Not however, in the same way that Le Witt uses variations on a theme of all possibilities.

The Max Reinhardt Haus Berlin Project (pl.29p42), a signature building for Eisenman, is an early example of the new "Transarchitectures"³⁶, a newer reactionary architecture: a product of a technological virtual construct.

³⁶ Symposium in Paris called 'Transarchitectures 02' exhibition in June 1997. Topics included: 'Exploration': Redefining the scope of Architecture'; The Issue of virtuality'; 'Reaching no Conclusion'; 'Touching on the Architecture of Paul Virilio's World of Dual Reality'; Words in Relief'. Architectural Design Journal Vol 68 No. 11/12 John Wiley & Sons Inc. London 1998 p62.



29 Max Reinhardt Haus Berlin project Peter Eisenman 1995



It is an inventive form of algorithmic design emerging from our Euclidean/ Cartesian/Newtonian legacy.

To the casual observer, Eisenman's buildings seem to defy the conventional logic of architecture, its rationality and even basic assumptions of top and bottom. Eisenman has said that architecture's most fundamental properties are not shelter and enclosure, and that his buildings are not about "subjective aesthetics." Rather, their skewed axes and geometry, grids layered horizontally and vertically, and compositions that are illegible, often times a seeming chaos of fractured and fragmented elements, substantiate his declaration for a "violated perfection." Nevertheless, such elements cannot be "dis-associated" from traditional issues

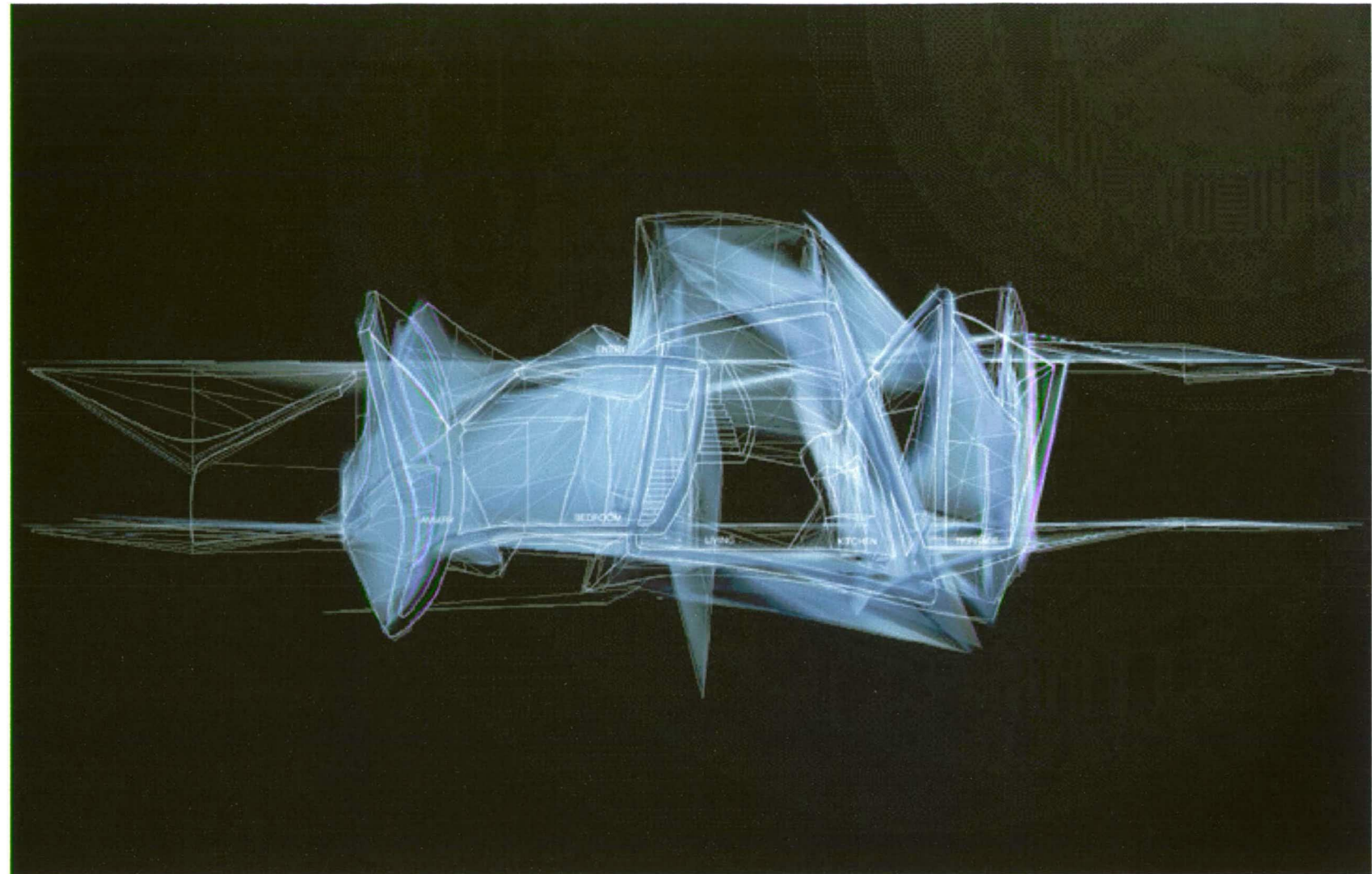
of space, technology, form, materials, or style, and Eisenman admits their role, if on a less important level. Inevitably, his buildings suffer from conventional criticism. They stand mute, like cold abstractions, intellectual exercises far removed from the experience of the average person, and not so few intellectuals. They seem monumental.

Eisenman obscures the creative sources and processes of his art. His conventional devices, such as his trademark grids, seem to work against expectations, if they work at all. The grids, used historically to order architecture, "dis-order" the logic of Eisenman's design and seem to layer his buildings as if to suggest shifting and simultaneous

temporal dimensions and logical structures. The materials and technology he uses are not only distinctive of modern architecture, but also make Eisenman's difficult constructions possible, even though they are at times juxtaposed with a surreal quality.³⁷

The new architectures are being built from invisible information evolving from within cyberspace (pl.30) where systems isomorph between the conceptual and the

³⁷PresidentialLecturePeterEisenmanEssays,RichardJoncas.htmhttp://prelectur.stanford.edu/lecturers/eisenman/joncas.html (citation for web page)



30 Peter Eisenman Virtual House digital image 1997

perceptual, emerge from the inventive algorithms bringing data-driven new material objects as architecture.³⁸

The vectorial boundaries of visual object and its occupying vector space, are continually being re-articulated. Man made objects are having their forms resolved and embodied with the freedom of unlimited virtual space.

³⁸ Markos Novak *Next Babylon , Soft Babylon (trans)Architecture is an Algorithm to Play in.* Architectural Design Journal Vol 68 No. 11/12 John Wiley & Sons inc. London 1998 p21

CHAPTER THREE: HOW THE PROJECT WAS PURSUED

Introduction:

The project commenced with a series of transitional works having developmental roots in my earlier Honours year's research. That body of work was made up of images created from sets of hand made wooden tiles covered with laser copied images. The images used for the laser prints were the result of the experimental manipulation of enamel paint on the surface of water. The spraying of enamel causes air turbulence and this was exploited in the formation of an image. Then I used a mono-print process to lift the image residue onto a substrate. I reprinted a laser photo copied

version to wrap the surface of the wooden tiles. The tiles were pre-cut plywood to a geometric five fold symmetric pattern based on the Amman Bars grids and formations of the Penrose aperiodic tiling (as shown p8, pl1).

These tiled arrays were arranged to form clusters and groupings to sets of rules and grid-like structures. During the evolution of this work the basic geometry was simply a by-product of the tile's arrangement on a metal baseboard. A system of magnetic strip attachment was employed to allow for the flexible creation of different images and

clusters or groupings. These were adaptive interactive works, able to be rearranged into other configurations.

During this work it was evident that I would be able to study in greater detail some of the grid structures that were underpinning the tiled arrays. This heralded the beginning of the project. As Charles Jencks states in an interview in the architectural journal *Transition*... *architects are using an appliqué of ideas as ornament, pattern making, or geometrical problem solving, as for example displayed in Storey Hall.*

Charles Jencks also states ... *I refute that ornament is trivial and that only deep structure counts. Ornament is very important, iconography is very important and structure is important.*³⁹ An influence parallel to the various types of decorative systems of polychromatic ceramic tilings, exists for me in the contemporary use of Penrose geometry. Ashton, Raggatt McDougall apply it to their decorative systems in RMIT's Storey Hall. While I found the diverse use of the aperiodic Penrose tiling geometry in the interior of the building's main auditorium admirable, the exterior

³⁹ Michael Ostwald and Peter Zellner at RMIT, 16 April 1996 *An Architecture of Complexity* – interviewing Charles Jencks at commemorative opening of Storey Hall journal *Transition*, Melbourne

was disappointing; the casting in concrete, the dense green and purple render, and the grotto like tunnel, gave the façade a heavy and overbearing 'weight'. While the responses to the architectural redevelopment were mixed, the Storey Hall experience 'liberated' me giving me a free mind-set to dare to treat building surface and façade differently; causing me to re-evaluate façade.

The decision was made to study the formation of the drawing systematics, the divisions of circle and angles, the make up of the grids and how to generate sets of tiles and patterns using the sub-structures beneath the more obvious layers of tiling. As outlined in the introduction (Central

Argument), I was well equipped to begin a detailed analysis of the Amman Bar grids and, eventually, through many series of drawings and re-drawing, came up with a design of a knot⁴⁰ form for the Penrose rhombi. Initially this design was simply a two-dimensional black line on paper.

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⁴⁰ This knot design, incidentally, is an interlocking design. I remembered helping my father create an inlay-mosaic into a design for a courtyard when I was 15 years old. My father was a craftsman that often did decorative work with similar designs of Greek key patterns, geometric shapes and linear inlay.

Sometime before starting this project I was looking to design and make a signature rosette for the classical guitars I make. Within the tradition of guitar making, makers have created designs of sound hole decoration. Designs become synonymous with each maker.

During my initial investigations into the field, it was soon apparent, as I started to map out a bibliography, that there were several distinct lines of inter-connected research.

As stated in the introduction to the Context chapter I have always had an absorbing and compelling interest in geometry largely as a result of my draftsman, technical drawing, carpentry and joinery background as well as my

practice of guitar making. I have always felt compelled to uncover, probe and investigate new topics of interest, a credo instilled by my father to do things to the best possible standard of craft perfection. During a period of guitar making and repair work, I received a commission to repair damage to a Lute's rosette. This was my first encounter with the method of incised interlaced linear decorative pattern elements. A typical lute rosette (pl.17 p.23) is a fretted sound hole incised into the 1.5mm thick spruce soundboard to allow the sound waves to emanate from the body of the instrument. It has the unique properties of being both a soundhole and a decorative ornamental element whose crossover fretwork elements have an

engineered structural integrity preventing the collapse of the thin soundboard.

*The size and position of the rosette has a direct geometric relationship to the lute of which it is part. Depending upon the school to which the builder belonged, the rosette is centred either five-eighths or five-ninths of the way from the bottom of the lute belly to the neck joint. The diameter of the rosette is usually between a fourth or a fifth of the width of the soundboard.*⁴¹

⁴¹ Lyn Elder, *Lute Roses, delicate patterns are cut or sawn*. Fine Wood Working Techniques, Vol 1 p.170 Taunton Press Newtown, Connecticut. 1978



31 Arch rosette design for end grain mosaic for guitar sound hole decoration 1998

Throughout my many years of researching techniques and construction methods of lutes and classical guitars, it has become apparent that this system of decorative effect has been applied throughout instrument decoration and ornament. One of the most famous lute roses is the design known as The Knot of Leonardo da Vinci, which was adopted by lute makers of the time (pl.17a p.19). During the early seventeenth century the guitar was an instrument of the people of Spain but was also widely played by the Italian aristocracy. Most of the surviving Italian guitars have extensive ornament of exotic materials such as ebony, ivory and tortoise-shell, complex inlays, marquetry and engraving. Soundboards were decorated with delicate inlay

or patterns of mother of pearl lozenges set in black mastic, surrounding the sound holes of instruments. Sound holes were filled with parchment and descended into the guitar body in a series of layers. The rosettes were usually painted or gilded.

Rosette designs vary from simple concentric rings of light and dark, as in the early Panormo and Torres designs, to fantastically intricate patterns of multi coloured mosaic slithers of wood, less than 1mm square, all inlaid to a depth of 1mm in the sound board. The rosette, like every component of the instrument, has a role both of ornament and function. The rosette together with its reinforcing plate assist in the stiffening of the sound hole perimeter, reducing

any chance of spurious vibration effecting the instruments' sound. The carpenter from Almeria, Antonio de Torres, making instruments in Spain during the early nineteenth century, used restrained decoration.

His ornamentation was limited to the surround of the soundhole only. Torres innovated guitar construction, developed a thicker soundboard and modern strutting methods that did not rely on the stiffening effect of the decoration, permitting the open sound hole we know today. The design of my rosette has taken the form of interlocking arches spanning to adjacent columns (pl. 31).

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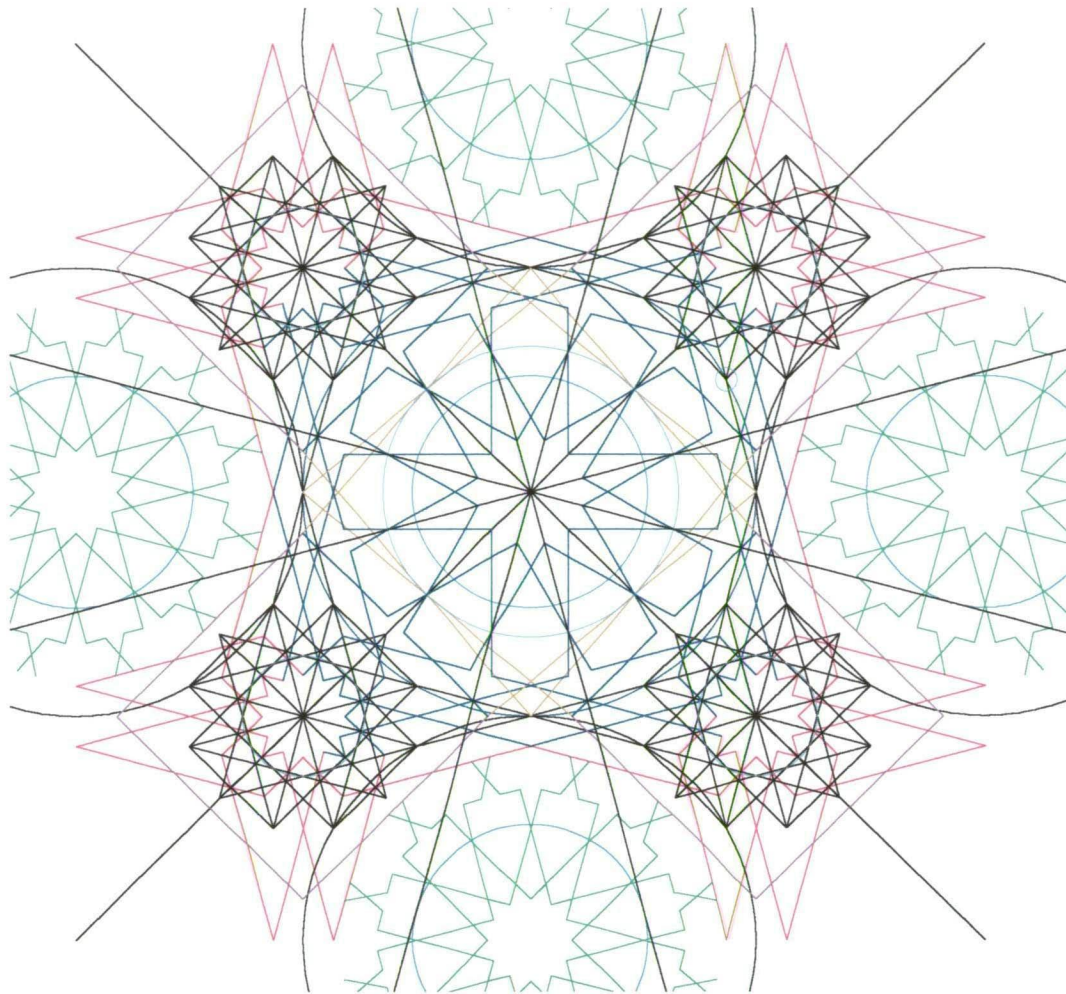
Systems underpinning the Islamic interlace

I have mentioned the Dover Publication reprint of Jules Bourgoïn's *Les Elements de l'art Arabe: Le trait des interlaces*, a facsimile book of plates of Bourgoïn's geometric construction pattern drawings of designs created by Arabic architects, decorators and craftsmen. As noted previously, the seventeen known symmetry groups have been proven to exist within the decorative tilings in the Alhambra. These together with various types of decorative systems of polychromatic ceramic tilings and Bourgoïn's drawings of interlace pattern have provided a rich source of influence.

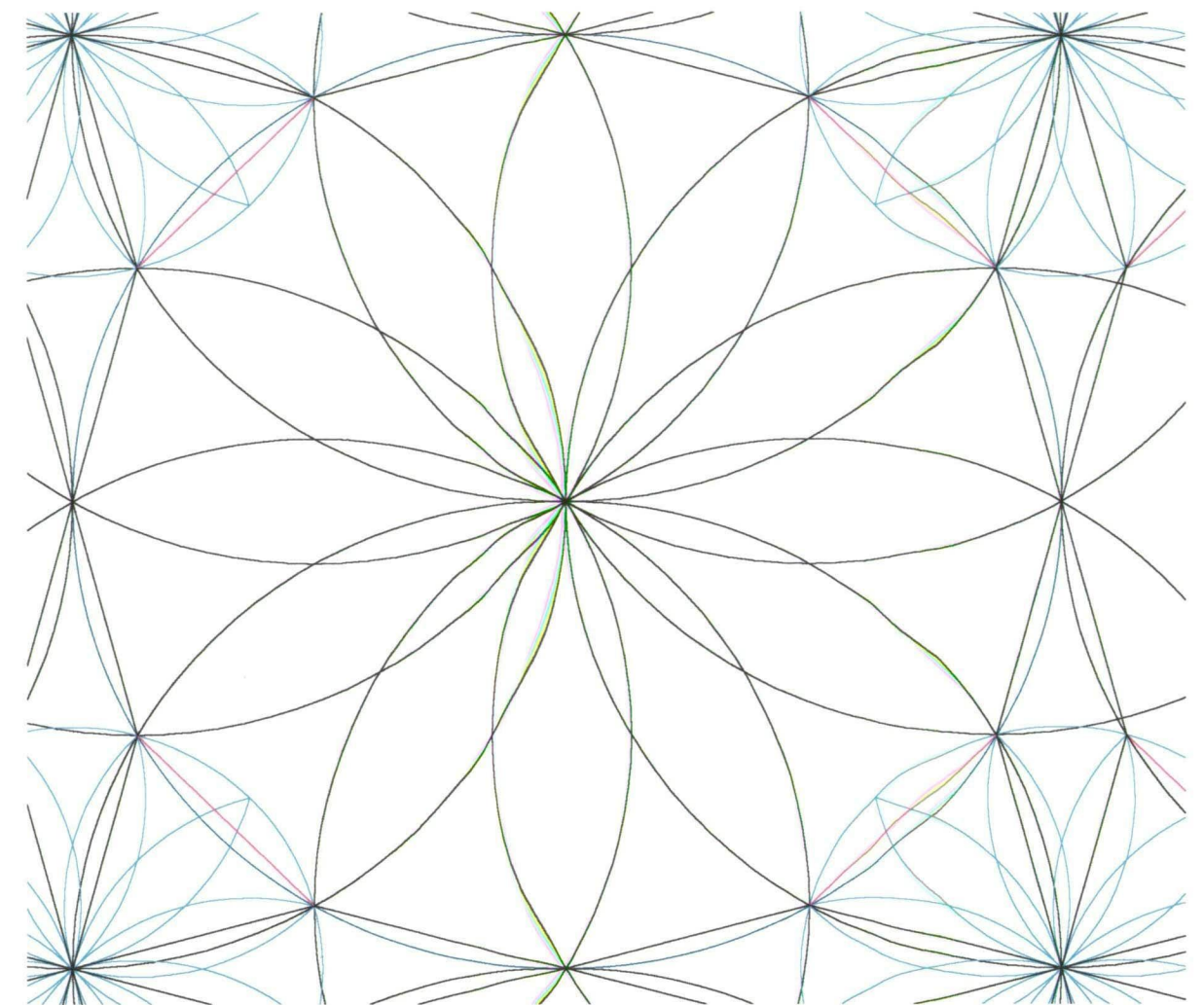
The early development of the interlace study began with the systematic perusal of Keith Critchlow's analysis of Islamic geometry, detailed in his book *Islamic Patterns: An Analytical and Cosmological Approach*. After reading all the text, I began what was initially simply an experiment. In the last chapter of the book he takes a pattern of Andalusian genius and walks the reader through the basic drawing of it. Over the course of three pages of diagrams, he describes how the basic pattern structure is created using the compass and straight edge. As a trial exercise I attempted to follow the diagrams described below...

... We take the North African and Spanish branch of Islamic pattern design and demonstrate another ingenious,

mathematical, manipulation of the archetypal polygons to produce new forms of tessellation and symmetry. Here the artist has taken the dodecagon as a central feature and placed it in such a way that the points of that twelve-sided polygon touch those of a similar figure within a square grid (these points of contact are circled in the drawings). The spaces between each of the dodecagons can, in this case, themselves be divided into twelve and give rise to a form of 'Maltese Cross' – four equilateral triangles each having its apex at the centre of the space between the dodecagons within the square grid. As this particular pattern of Andalusian genius has so many subtleties several more stages in its creation are shown. In the first stages of



Detail from PL.24 drawing analysis Interlace stage four diagram. (2003)



Detail From PL.24 drawing analysis stage 1 Interlace diagram. (2003)

development we demonstrate how the pattern of equilateral triangles with apex points meeting at the centre and possessing a twelve-fold division develops a new set of axes. In the next stage we demonstrate how the characteristic little four-pointed 'flower' feature of the final pattern is constructed from the geometrical procedure of the previous illustration, and how the extensions of the angles created in this pattern link right through the tangent point to the twelve petal 'flowers' of the major centres.

The last diagram shows the completed pattern with (in colour) the same underlying primary grid. Here we can see the way in which the artist of the 'Alhambra' in Granada has been able in a sense to vary the 'pitch' of the musical

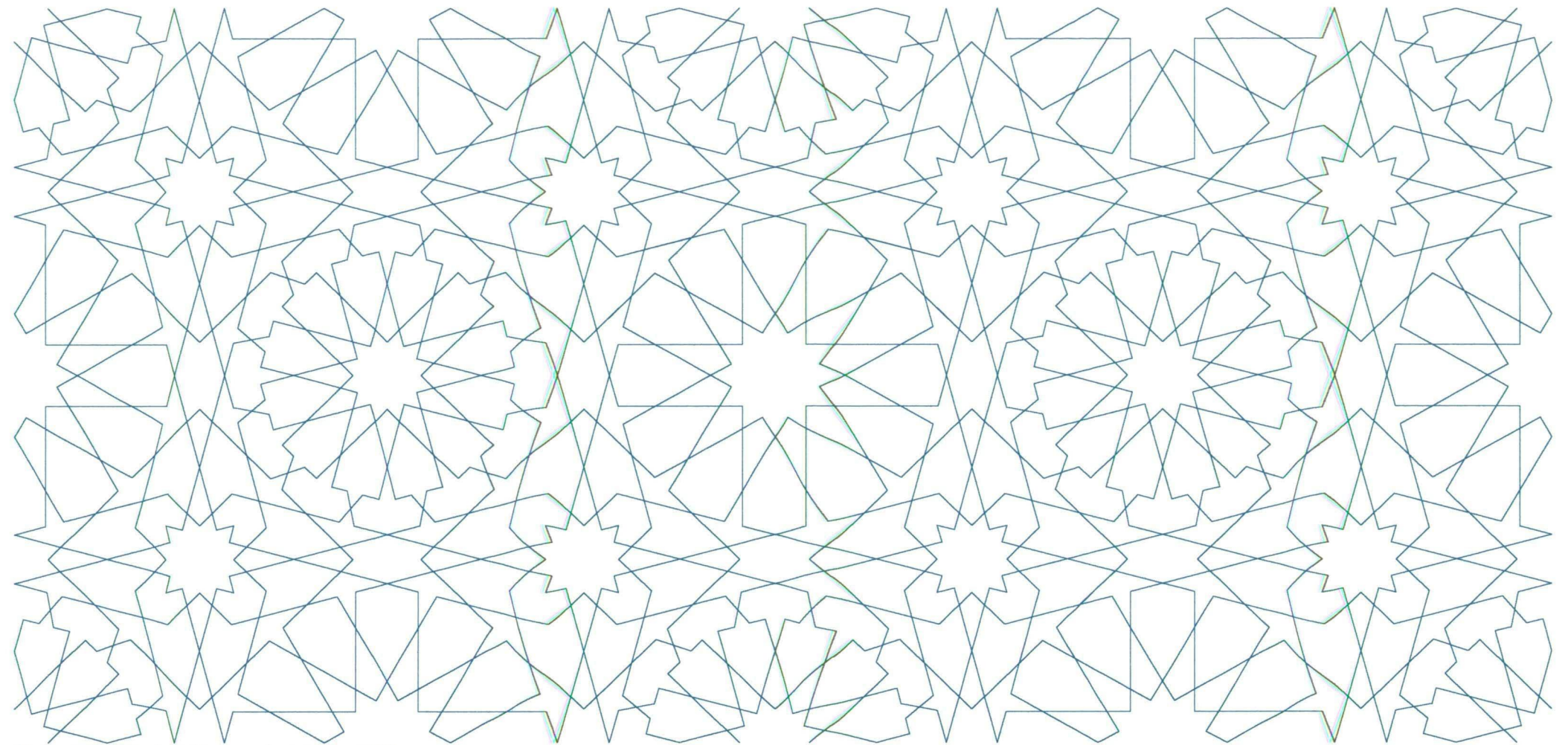
notes of his compositional pattern. The twelve-petal 'flowers' have changed in character, in the four lateral dodecagons, from that of the central one. This theme is varied many times in the halls of the 'Alhambra', it is found frequently on buildings in Morocco.⁴²

The first drawing depicts a circle divided by a series of arcs of the same radius as the circle twelve times (pl.24). The diagrams in this book are selective in that what they show of the construction is separate sets of lines on each page. Now when one tries to draw the pattern in the manner of the

⁴² Keith Critchlow *Islamic Patterns An Analytical and Cosmological Approach* Thames and Hudson London 1995 p178

description using the diagrams as a guide, the drawing's complexity rises exponentially. As each constructive line is completed, and the developing sets of lines are drawn, it is almost impossible to maintain a continuous comprehension of the line-work. It becomes a spider-web where one is easily lost. If one is completing a set of lines which have all the same characteristics, and the set calls for repeated multiples, if one happens to either stop or lose count, relocating and deciphering what has been done is very difficult and time consuming; the web of line-work can soon overwhelm.

In following Critchlow's text, and using his diagrams as a guide, one comes to the realisation that a good deal of the



32 Centre line drawing of Ambassador interlace. 2000

necessary information to get to the completion point of the drawing is lacking and needs inordinate amounts of time, lateral thinking and deduction to discover. I soon realised that I had to teach myself how to apply the principles to other parts of the drawing to extrapolate the whole. It required an extensive study of the elements of the drawings and the tiling panels over a period of two weeks to arrive at the completed centre cell drawing with some comprehension of the principles involved. Being able to survey and map the layout design drawings by systematically developing each construction drawing line in a sequential and controlled process, through the 'hands on' experience, has given me a new comprehension of the basic

tenets of this form of geometric reasoning. Each successive drawing layer uncovered amazing coincidences and points of harmonic relationship between individual sections of line. Finding out how the straight edge and compass was used by the designer of the pattern would determine the thickness ratio of a path or line of the pattern. How it may be found by joining neighbouring interspaces ie. lines from two adjacent cells or elements. Experiencing the complexity of these drawings first hand provided insight into the variety and diversity of skilful techniques and methods employed by the designer using only compass and straight edge for the practical layout of his design for ceilings or tile panels. During the drawing of the

Ambassador Interlace, (pl.8 p.11) I completed the first central large cell drawing with the aid of Keith Critchlow's analysis.⁴³ I then commenced a drawing on a scroll of drafting film (length 5 metres) using a system of overlay, drawing a tracing of each element of the interlace and systematically logging each. This sample of pattern was used as a base grid for the creation of a drafting film mapping analysis that systematically logged each member element pathway using a different coloured pencil.

⁴³ K.Critchlow *Islamic Patterns an analytical and Cosmological Approach* Thames & Hudson, London, 1995 p.180

This process proved a practical solution to understanding the elements' operative roles within the design.

Tracing the pathways in colour led to the uncovering of a 'Recursive Loop' (pl.11 p13a).

Further scrutiny of other different interlaced patterns revealed that this feature was largely unique to *Ambassador Hall* interlace design. The drawing revealed some of the mathematical beauty and science hidden within the line framework of these tessellations. It also revealed some of the knowledge evidenced deep within the hidden underlying line framework of these constructive pattern drawings.

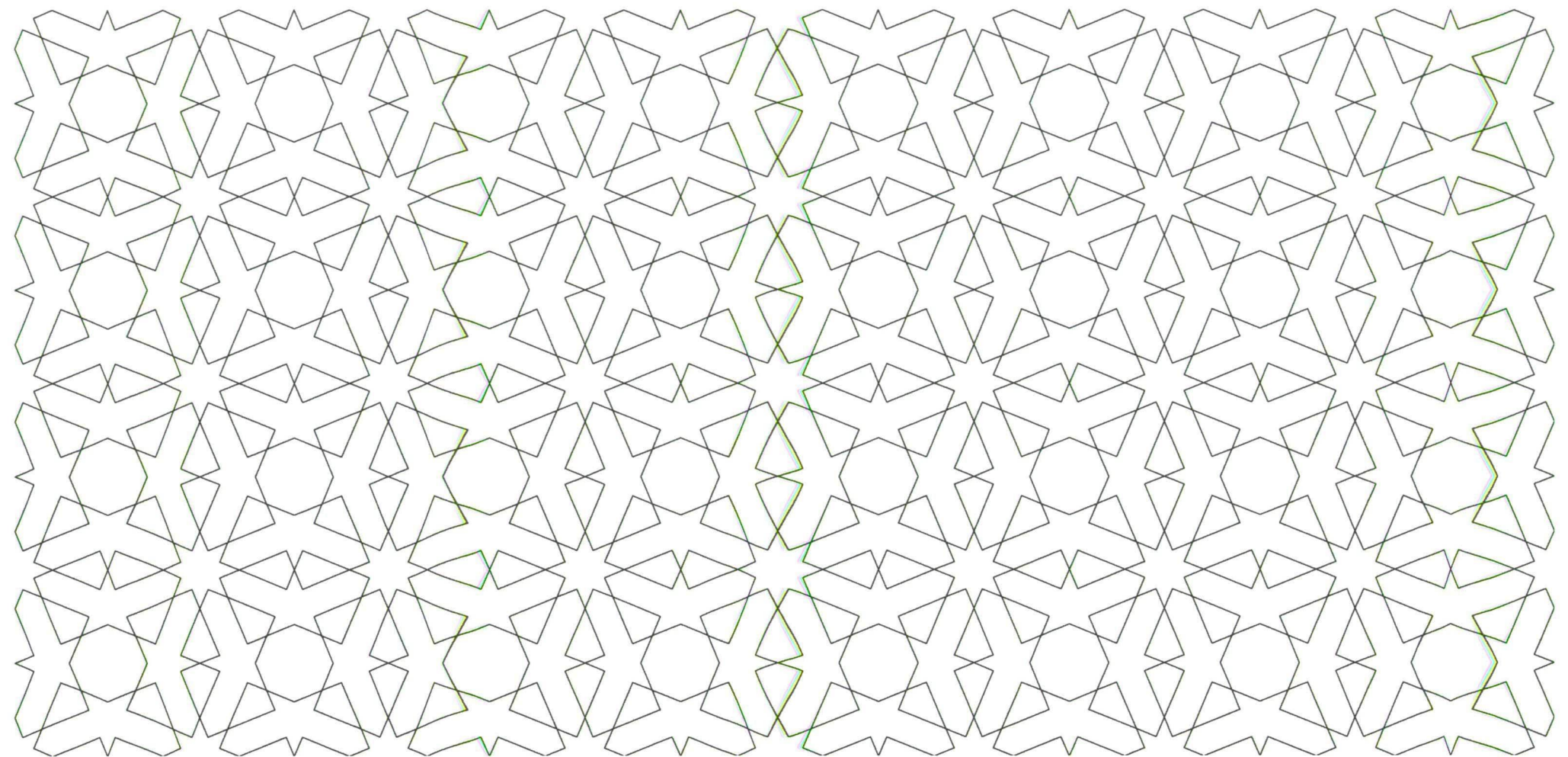
The technical drawing first used in the research of the interlace path tracing analysis used traditional techniques, process and applications of rules; a hierarchical structuring that has always been a language for architects, designers and builders. It has currently undergone re-invention and adaptation to change with the application of the computer in the process of both design and construction – increasingly being taken up by both builders and architects. Projects now have teams of CAD specialists, even CAD managers.

It is with this form of conceptual tool process that the CAD three-dimensional modelling environment is allowing architects and designers to rethink their working strategies. Eisenman was one of the first to begin work with these strategies; others include Rem Koolhaas, Frank Gehry and Zahir Hadid (whose latest work, the Phaeno Science Centre in Wolfsburg is currently under construction).

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33 Bourgoin # 44

SYSTEM 1 – Latt-tile - Solomon experiment

What interests me in the Islamic geometry is the idea of the unseen, by unseen I mean the constructive hidden geometry. To me this has the most exciting potential for future exploration using computer technology.

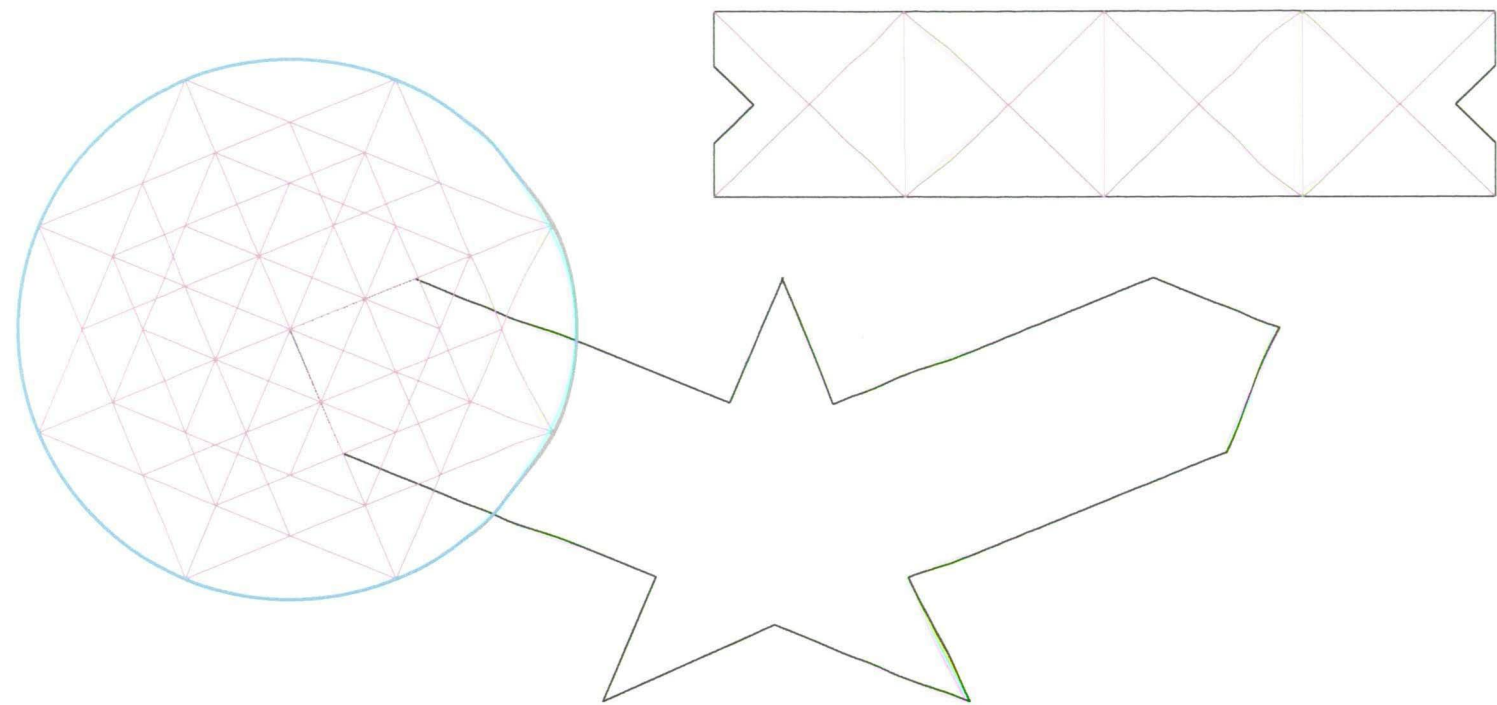
An analysis of the plates *Bourgoin # 44* and *Bourgoin # 45* (which I will refer to as *B.44* and *B.45*). shows that the *B.44* has a core cell comprising an eight pointed star which is surrounded by eight kite elements, four of which touch the apex of an octagonal polygon; the other four kites touch a repeated group of the same eight kites (another cell). The grids that carry the cells are overlap each other. The

extreme simplicity of this design and the optical visual experience it generates was fascinating to draw. *B.45* is a variation of *B.44* and has a much denser field of line work. The simultaneous grided star is the same but the octagonal polygon is smaller due to the inclusion of eight 30° pointed rhombi spaced radially 45° apart, connected to the base point of the kites.

Within the line work of *B.44* is an underlying $\sqrt{2}$ logic in the form of the four-fold octagonal division of the circle. The circle that generates the star is the major activator of one grid which allows for the minor circle to be tangent to four major circles which in turn forms an overlapped grid.

Each of these grids carries the elements generating the pattern. With *B.45* the major circle is eliminated in the construction drawing and the positioning of the star and octagon is reversed.

The subtle changes in the Arabic designers' choices in these two particular construction line drawings has a major effect on the complexity of the line work. While the elements are essentially the same vastly different patterns emerge. When *B.45* is drawn as a single even-weighted black line on paper, it has many interesting optical effects happening within it. It was instrumental in my research for its lattice of line work. It was this particular lattice that caused me to



34 Solomon Latt-tile module harmonic diminutions of the dynamic square (diagonal) inside the passive square giving rise to square root of 2 harmonic ratios.

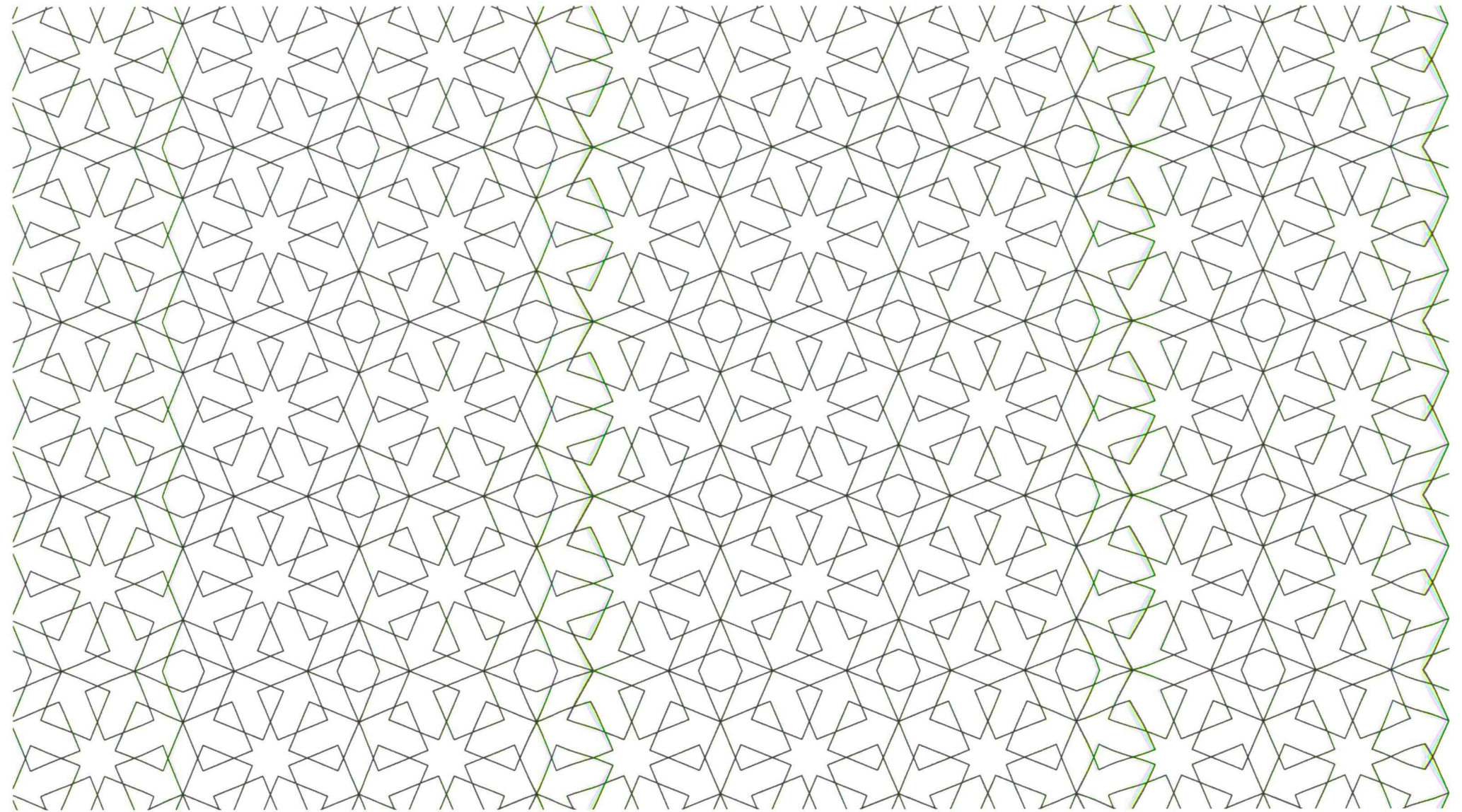
re-evaluate the earlier wall-bound solid tilings and shift my focus towards the creation of a module that could be both tile and lattice.

It was at this point that I began a drawing of *B.44* using a compass. I began to divide the circle with eight arcs using its same radius. When it occurred to me the pattern elements were implying the existence of a third element, which had initially gone unnoticed, I began to see this 'bird' shaped element. On careful examination it can be seen as the only element needed to generate the design. At this point the penny dropped that I could isolate a single element from what was seemingly a very complex array of lines on paper. I then changed tack with the drawing

method, focussing not on the circle, but on the 'bird' form itself. I was using my engineering drafting machine and drawing board for this drawing. A feature of this drawing machine is that it can be pre-set to angles as multiples of fifteen degrees and that one can quickly ascertain or draw the shape of a polygon. It was while doing the drawing of the *Bird* module that I discovered its constructive logic embodied the $\sqrt{2}$ harmonic ratio. When the lengths of the sides are considered in relation to the width of the element, or the 45° end point is placed adjacent to seven others in a circular configuration, a Solomon star is formed. Each point has the naturally occurring $\sqrt{2}$ ratio. It is possible, because of this harmonic, to draw this element in a way that

does not require any mathematical measurement or calculation or external influence. The only tools required are compass or dividers and straight edge; it is harmonically derived as a product of Euclidean geometry intrinsically beautiful in its simplicity (pl.34).

I soon realised that all of this particular module's main dimensions and properties were in 1:1.414 ratio; a $\sqrt{2}$ Euclidean geometric structure which offers an infinite number and range of different rotational and transpositional mapping of the module against itself.



35 Bourgoin # 45

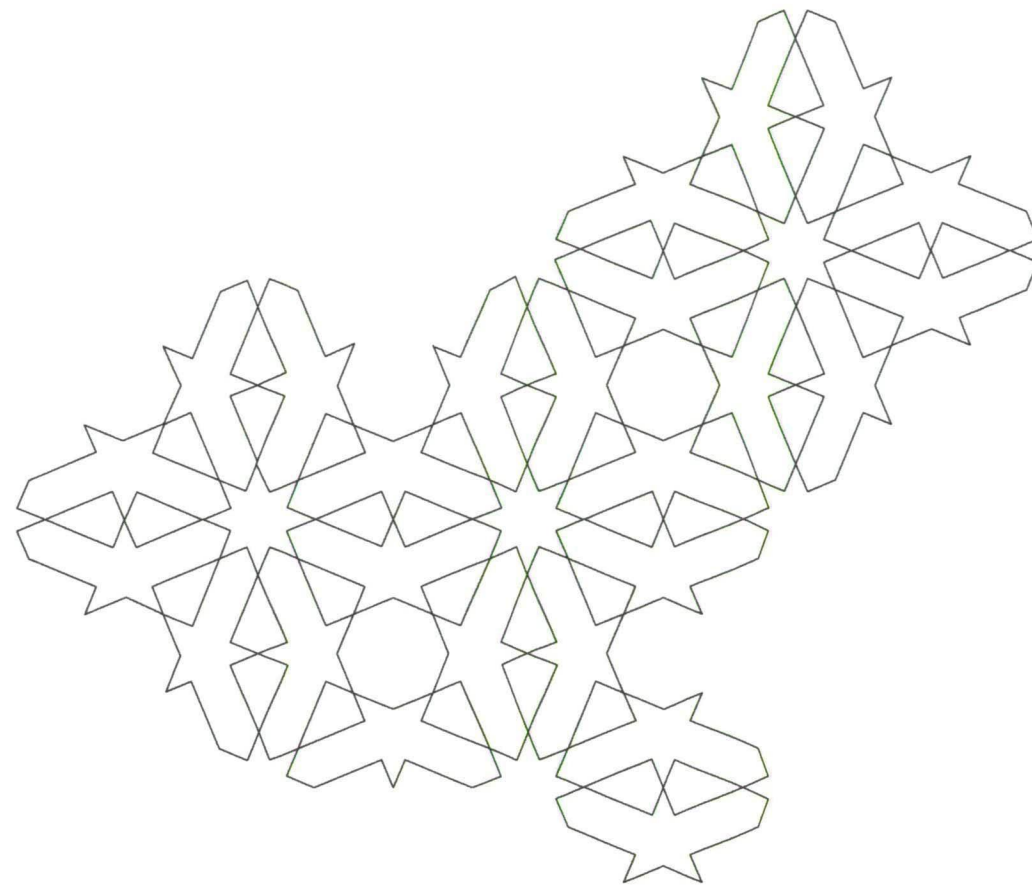
Creating a lattice from a singular element, which in itself contains no logical connections or clues to its purpose was a major breakthrough in that it reinforced the importance of continuing with the commenced process and study of the interlace drawings. The changes to my own drawing methods have been profound and has forever changed the way I look at geometric patterns. The resultant works are the *Latt-tile* aperiodic series and the *Solomon Bird Latt-tile* series. I can see the potential for more drawing research of this kind within future works. Research on these particular patterns and their constructive geometry is now on going. By being able to set up a unique grid structure of my own derivation of interlaces or lattice, I can create a base

working model of it in the computer. Storing sets of these work models for incorporation into future works has allowed me to use the models as conceptual starting points for the development of new forms, in turn applying the principle in serialised variations, and permutations.

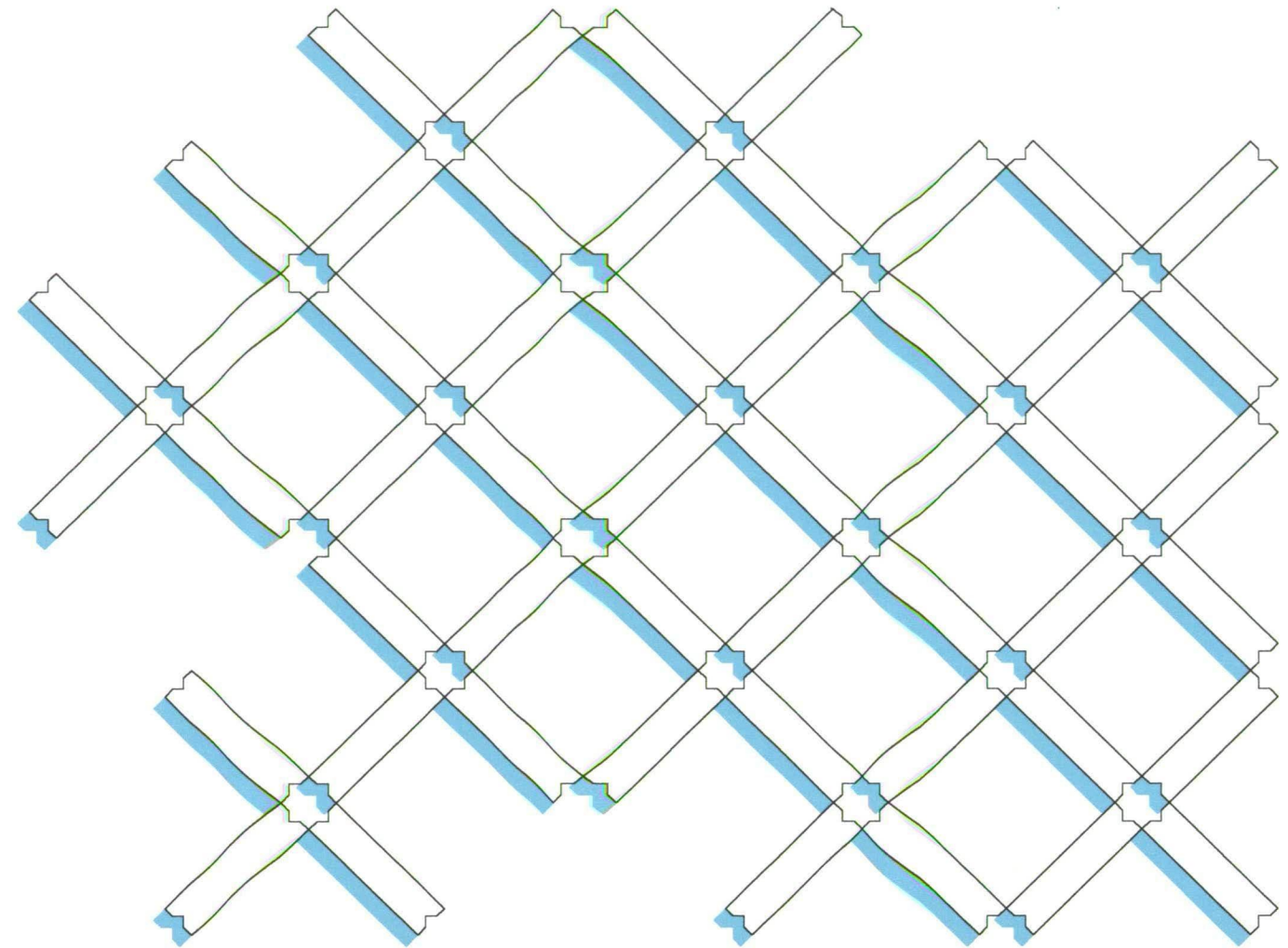
The commencement of interlace drawing analysis was under way at the same time as the developing *Latt-tile* work. The then commenced process and study of the interlace drawings was revealing the importance of the singular line-on-paper drawing in front of the designer and the visual role it plays in the design. Finding concepts for suspension of the 'Latt-tile' now became a primary goal.

Initially my aim was to design a system of applied ornament, utilising the previously developed tiles. Many different configurations of tilings were tried. Some problems were encountered during the studio-based experiments. I developed a system of making small maquettes of extracted elements cut out of thin card, placing them on a metal backboard as had been done previously for other work. Arranging sets for photographing was creating issues of how to deal with the edge of the tiling clusters. How to create a satisfactory resolution of the perimeter?

The tiles fitted up against walls and floors in the conventional applications always needed a specific boundary edge design. I could see the limitations of this in



36 Solomon 'Bird' Module cluster



36a Solomon Lattice 001

a practical sense. The boundary issues remained a problem until the idea of floating lattice work modules (suspended initially on nails) off the wall in fragmented clusters was tried (pl.36). The issues of boundaries then became easier to deal with and gave greater freedom including options to vary scale to suit particular applications.

Previous testing of modules on the magnetic board in chance configurations had presented both predictable and unique random coincidences and results. This furthered understanding of some of the principals involved in the construction of these pattern systems. Understanding the potential to use this sort of logic was beginning at this stage.

During a session of testing maquettes of the Solomon 'bird' modules I observed a curious natural effect taking place on the wall directly adjacent to the floating modules' shadow; an additional lighter shadow, an intensified reflected light was emanating from the rear of the tile. Responding to this observation I set about the task of cutting out a sample of the 72 ° and 36 ° pointed Penrose rhombi (the previously drawn line-on-paper interlocked knot configuration). I used the 'luthier' technique of pasting a paper line drawing of the pattern onto the surface of the board and, using a sharp knife, I made many light consecutive cuts through both the design and the mount-board to make a fretted sample of a few of the modules (pl.7b p12). It occurred to me then that

a suitable name for this product would be a combination of the words lattice and tile - 'Latt-tile'. This initial maquette cut out was in black mount-board and as such still had the remains of the white paper design drawing on the rear side, as the sample was positioned off the white wall a variety of subtle light effects were noted. Variations of mounting distances were tried to establish the most visually interesting shadows and reflections. I also noted that multiple light sources would provide increased visual complexity.

I then undertook a series of experiments, employing a range of treatments to the surfaces. The first option I thought of was to apply paint to the rear surface. The first colour

chosen was cadmium yellow. This yellow turned the usual whitish reflected light into a subtle pale yellow shadow. Further testing of clusters of 'Latt-tile' on coloured background walls proved less successful as configurations were most often best on white walls.

Furthermore, at this time I realised that there was the potential to develop a complete system of fenestrated tiles. The Penrose rhomb would be ideal with its aperiodic geometric complexity, and the '*Bird*' series element would also be adaptable. The knot design is one design that has been worked out to suit the rhomb. It has provided a vehicle for the initial development of the tiling system

however the principles of the system are able to be adapted endlessly through the use of CAD software.

It was suggested during an early 'crit' discussion of the Latt-tile system that it could be used on a much larger scale either architecturally for an interior ceiling decorative system or applied to, or alternatively incorporated in, the design of a building surface / façade. On returning from the 'crit' to the studio and the drawing board, the possibility of applying the Latt-tile to a ceiling format became apparent but a suitable means of layout and structural framework would have to be worked out. The Latt-tile modules can be scaled to suit different applications – a full aperiodic patch

contains approximately one hundred and seventeen (117) modules of four different rhombi, mirroring and stretched ie. with the K linear knot design.

The 'Latt-tile' and the '*Bird*' series were initially being hand drawn on the drafting board, printed onto sheets by photocopier and pasted onto 6mm thick plywood sheets, and the design cut out by fretsaw and jigsaw. I changed from cutting the individual units from sheets of ply to a system of breaking down the large sheets into smaller blanks, using joinery shop jigging methodologies. I cut multiple angles in a systematic series of operations on my table-saw in order to streamline the production. After tedious hours of

following the black hand drawn line to achieve the fenestration using the jigsaw it soon became evident that a move to the computer was inevitable. I had previously seen computer guided high-pressure water jet systems for cutting ceramic tiles and terrazzo floor finishes on building sites in Melbourne. Likewise I have used plasma cutting technology for cutting steel. It occurred to me after hours at the 'cutting-edge' that the newly developing CAD-CAM⁴⁴ technologies were ideal for achieving efficient and large-scale production of the Latt-tile system. Because of the computer and the ability to CAD-CAM one can easily alter

⁴⁴ CAD (computer aided drafting), CAM (computer aided manufacture)

and change the dimensions of the Latt-tile at whim opening up the flexibility of the system. With the option of being able to out-source the manufacture of modules, it became important to address issues regarding the limitations of tooling cutter head dimensions, the materials being cut, and the finishes applied. I knew that any possible limitations would have to be factored into the design criteria when developing new designs.

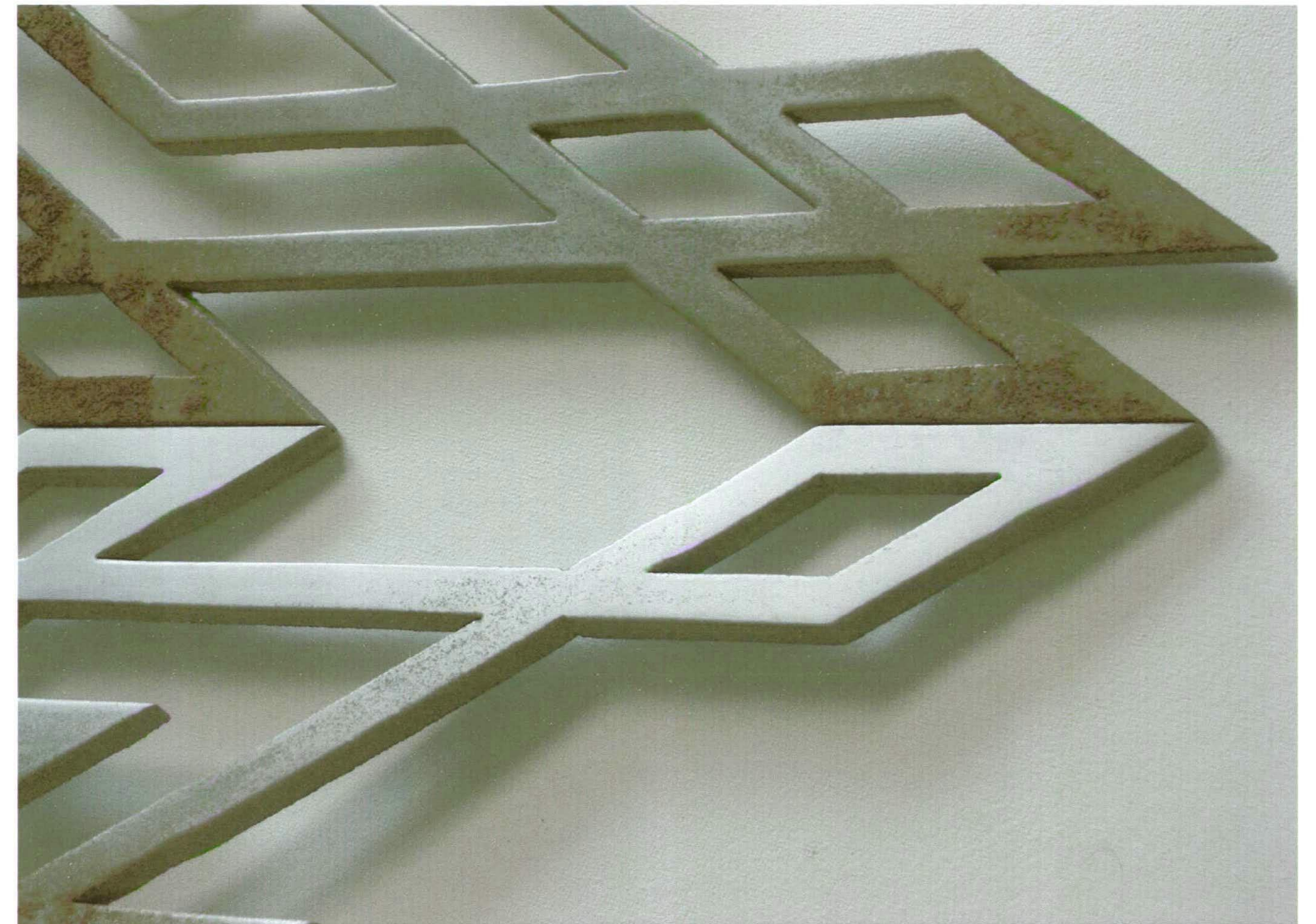
The intrinsic qualities of the $\sqrt{2}$ ratio operatives in the determining of the 45° point of the 'Bird' element drew my attention to a simple effect created by a revetment tile. In the Alhambra there is a revetment panel of tiles comprising four narrow tiles in a 45° diagonal lattice formation

surrounding a darker tile: each narrow tile has a notch in each end. The narrow tile when placed around the perimeter of another tile creates a Solomon star at each junction. In this ceramic tile pattern the star itself is a tile that is sometimes a colour different from the main tile and the narrow lattice tile is most often white. This was the beginning of analysing each tiling system from a different viewpoint.

Concurrently with the development of the 'Latt-tile', the interlace drawing analysis was under way and was done during the process of experimenting with transparent colour effects and the visual effect of the interlace elements set against each other in differing colour combinations.



37a Axolotl metal finish



37 Detail Latt-tile 2004

Creating the 'Solomon 001' series was a demonstration concept for a lattice made from a singular element, which in itself contains no immediate logical connection, (such as a piece of jigsaw puzzle etc). This was a major breakthrough in that it empowered the potential of the system. Many surface treatments such as paint, laminates, sign-writing tapes were all tested on various substrates for their effects. Apart from the hand-applied paint, the rest were discarded.

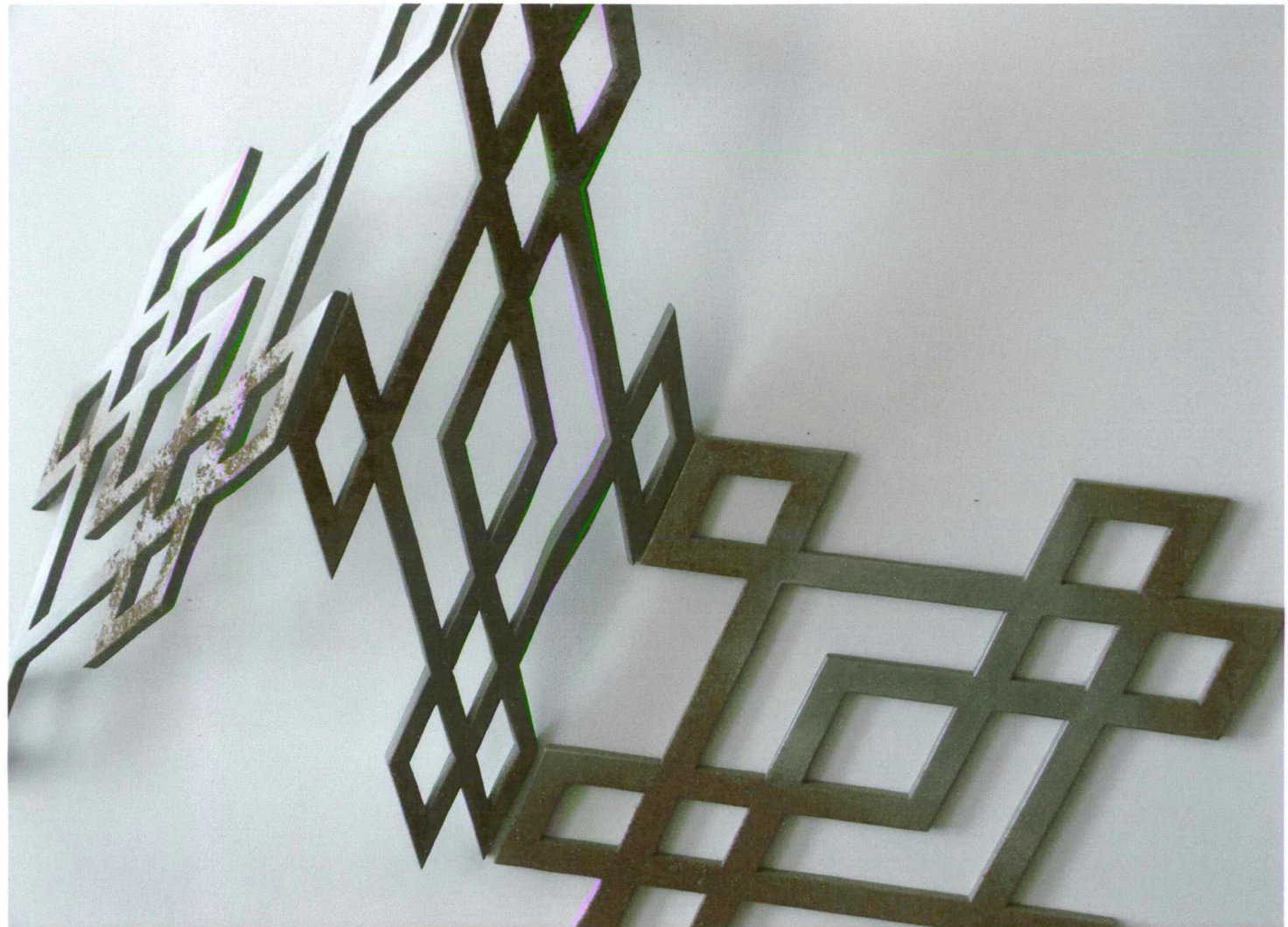
Through my subscription to an architectural trade journal, I discovered *Axolotl*. *Axolotl* is a specialist metal finishing company. It produces authentic and unique metal coatings for interior and exterior surfaces. The technology involves

a liquid metal application that utilises real metals. Metals such as bronze, brass, copper, aluminium, stainless steel, pewter, nickel, zinc and a variety of alloys are available. Within these broad categories there are a number of texture variations and colour options including the application of patinas and rusts. The finishes extend the design and construction potential of any substrate by allowing that substrate to be treated as if it were solid metal (pl. 37).

The Latt-tile can be manufactured from any of the following materials that have a stable surface such as custom-wood (MDF), ply wood, plaster, CFC, ceramics, metal, glass, acrylic sheet, polystyrene, or even concrete. Latt-tiles made from any of these substrates present an ideal

vehicle for the use of *Axolotl* metal finishes. I have used polished aluminium as a coating for the Latt-tiles and combined, as is possible with *Axolotl's* technological process, with a dusting of rust in some areas. This, of course is a paradoxical marriage of metals since aluminium does not rust.

The MDF substrate of the Latt-tiles sent to *Axolotl* in Sydney had to comply with their requirements for a 1mm radius on each sharp edge or angle to enable the metal to be worked by the finishers. My requirement was for a sharp edge with no radius. Through consultation with *Axolotl's* technical and design team we each met our parameters. The application is not a paint but a thin (0.5 – 2mm) layer of



38 Latt-tile Hinged 2004

durable weatherproof aluminium (or other chosen metal). Their metal finishes are warranted not to de-laminate or crack, are impervious to extremes of heat and cold and are UV protected, rendering them suitable for all climates and geographic regions. An advantage of using this coating technology system applied to a lightweight substrate is that it gives the illusion of solid metal without greatly increasing the overall weight of each element.

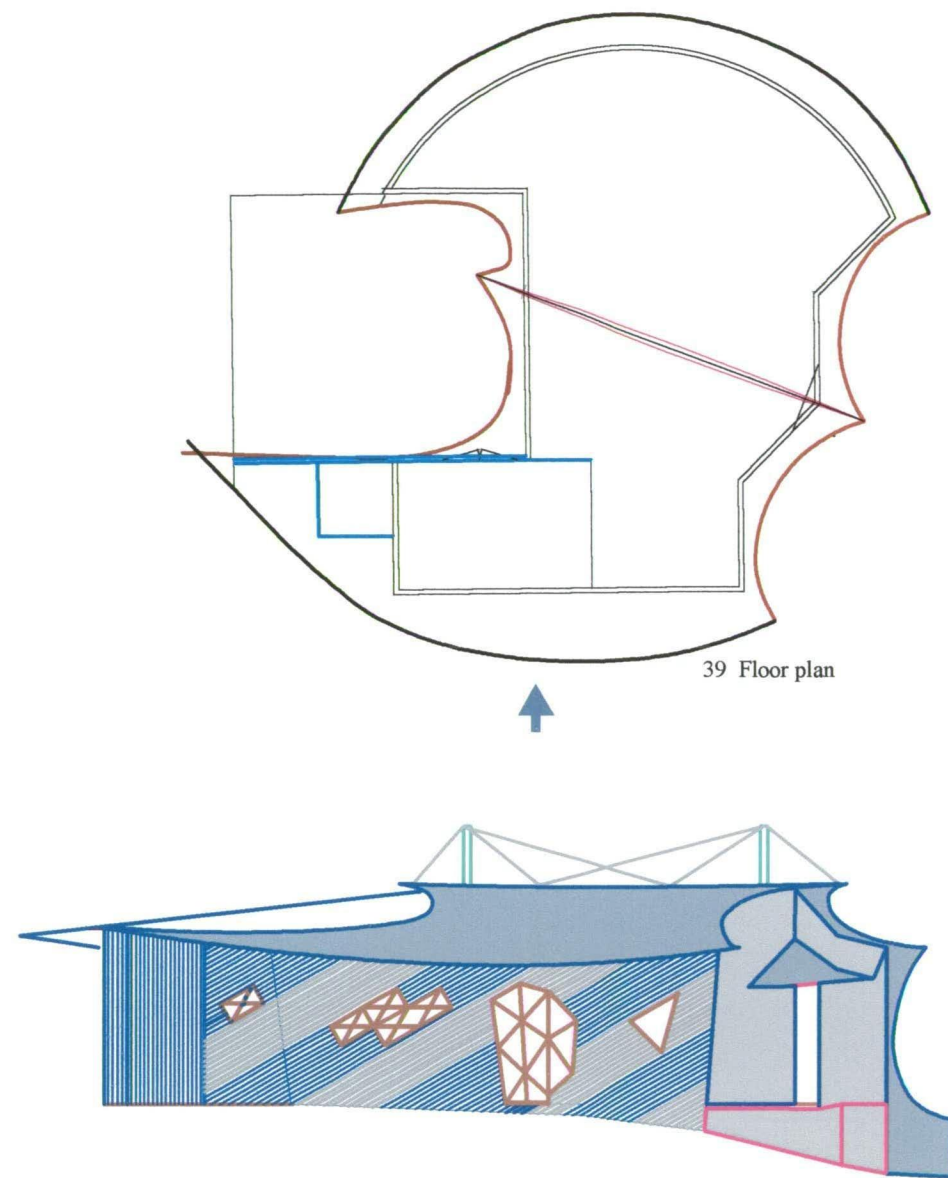
The *Axolotl* process offers the Latt-tile system great latitude and variety of application. The Latt-tiles combined with *Axolotl*'s unique metal coatings can be used as an ornamental system, or design elements, in all manner of markets: architecture, interior decoration (ceilings, screens,

railings, panels), signage, sculpture, shop and corporate fitting, even furniture. My original concept was that externally Latt-tiles could be used to decorate, redesign or reinvigorate tired building façade or, in the case of high-rise building, to renew the curtain walling or fenestration. This exciting finish system combined with my treatments to the rear surfaces of the Latt-tiles and the subsequent reflected light characteristics, offer a unique form of ornament providing a versatile two-fold function; light effects and kinetic display of shadow (pl.38 & pl. 39).

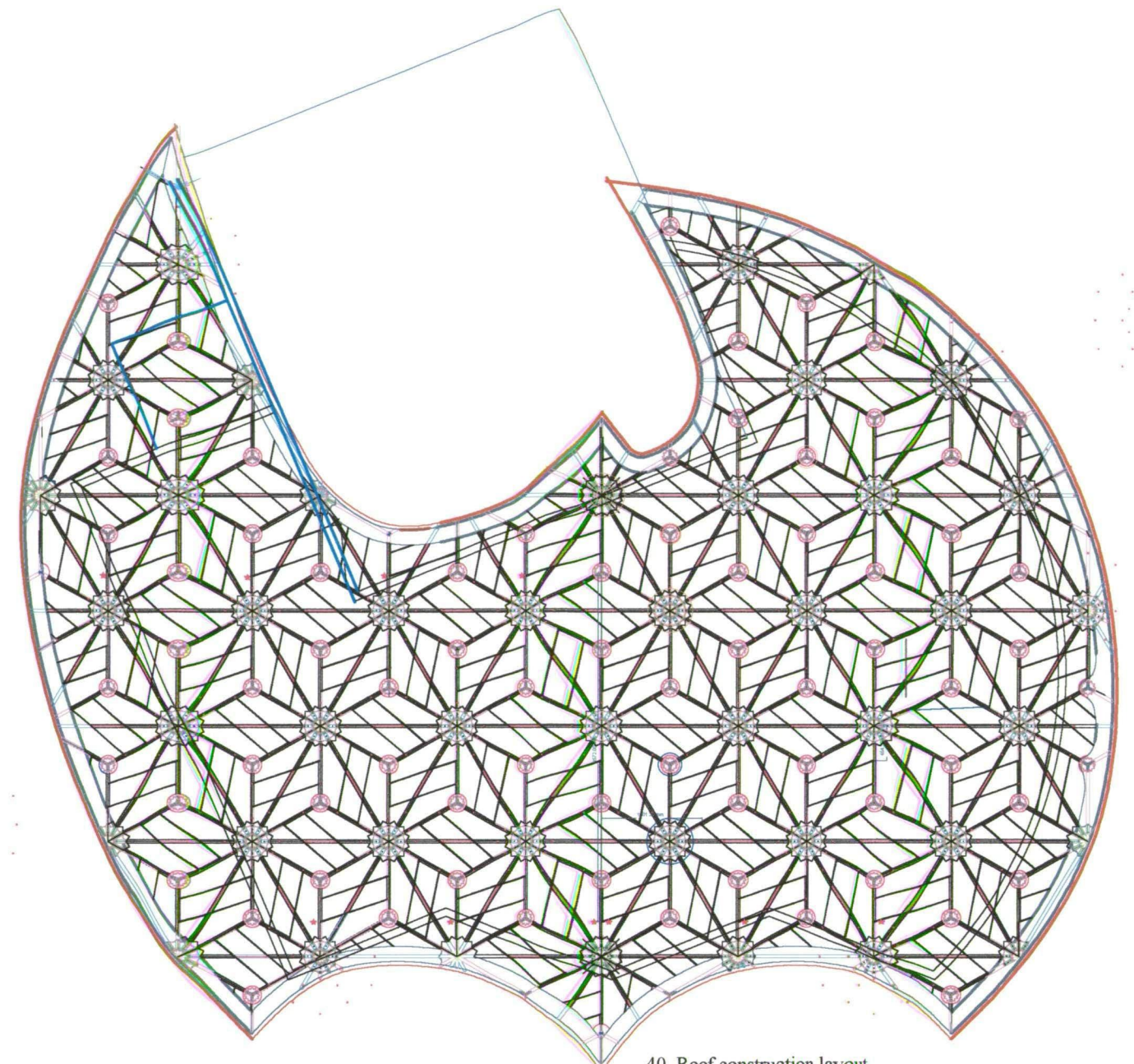
Mounting the Latt-tiles demands a suitable fixing technique: various systems have been developed and are

adapted to the requirements of scale. Also the tiles do not have to be static they can be made as moveable units, or have parts that move.

The knot design overlayed to the rhomb shape has the capacity to be flexible. To modify the design of the Latt-tiles within the CAD program, either to re-scale or reshape. The interlocked knot lines are grouped into a poly-line cell. This action allows the manipulation of the design without changing line structure or vectors, every element stays in the same relationship to each other.



39 Floor plan



40 Roof construction layout

The set of rhombs is derived from the single design drawing through the process of interchanging the X and Y axis length of the 36° sharp pointed rhombs to the 72° blunt point. New X and Y dimensions are entered into the re-scaling co-ordinate fields in the inspector bar and a new reshaped drawing of the cell is done automatically by the computer.

** ** *

SYSTEM 2 – CEILING/ROOF SYSTEM

The development of gallery wall mounted constructions and module units continued throughout the project but the focus moved towards ceilings and the visual properties of the complex fields of geometric pattern and the effects one could create overhead. While continuing on the Latt-tile project, in particular the ‘Solomon’ and ‘Bird’ module series, I began a new project. *The design brief:* An opportunity arose to integrate development and design of a ceiling/roof system as part of a building project for a new

studio/workshop and gallery building of some 140 square metres in area.

The building is of corrugated steel-clad construction encompassing a multipurpose workshop/production space and a large open exhibition or performance space. The brief was to maximise the versatility and functionality of the building’s spaces. It was the requirement of a large open space that prompted the idea of a lightweight suspended roof form.

The site presented a northerly aspect as regards sunlight. Access and other logistical concerns largely controlled the shape and dimensions of the building floor plan. The spans

presented by the required open space would, under conventional construction techniques, have required a number of heavy beams or rafters either of steel or laminated timber. The initial concept for this roof/ceiling came from observations I made during a research test of the flexibility of corrugated steel sheet roofing materials.

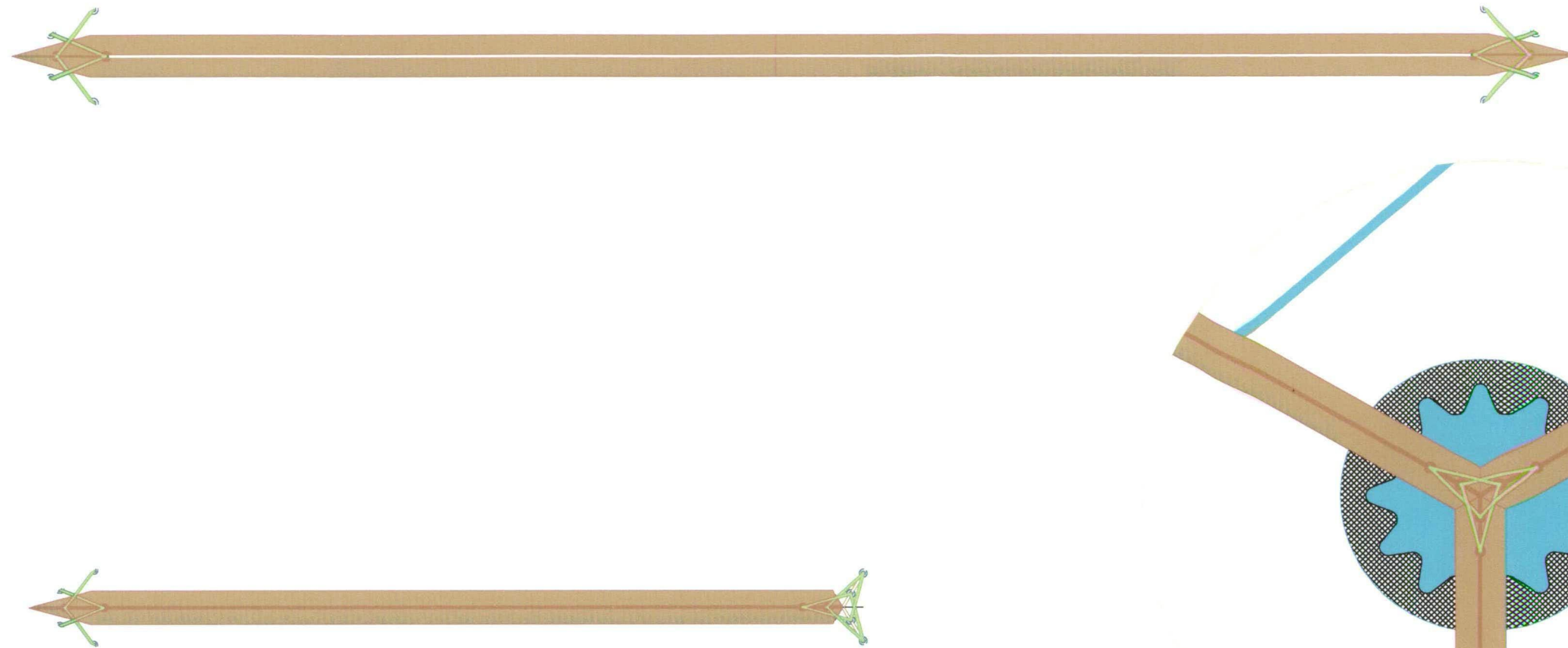
The basic observation was that when you support a 6 metre long sheet of corrugated steel at one end approximately 1500mm off the horizontal the sheet has a naturally occurring droop of 300mm mid-span. These physical properties were being explored for installation requiring bending over a conventional convex form of

battens/rafters/beams, chiefly for the economy of not requiring a pre-rolled formed sheet. The design outcome was a tent-like structural system that would be both the roof and ceiling combined as a singular, stressed skin, using the natural downward droop of the materials' properties to dictate the curvature and free form lines of the roof.

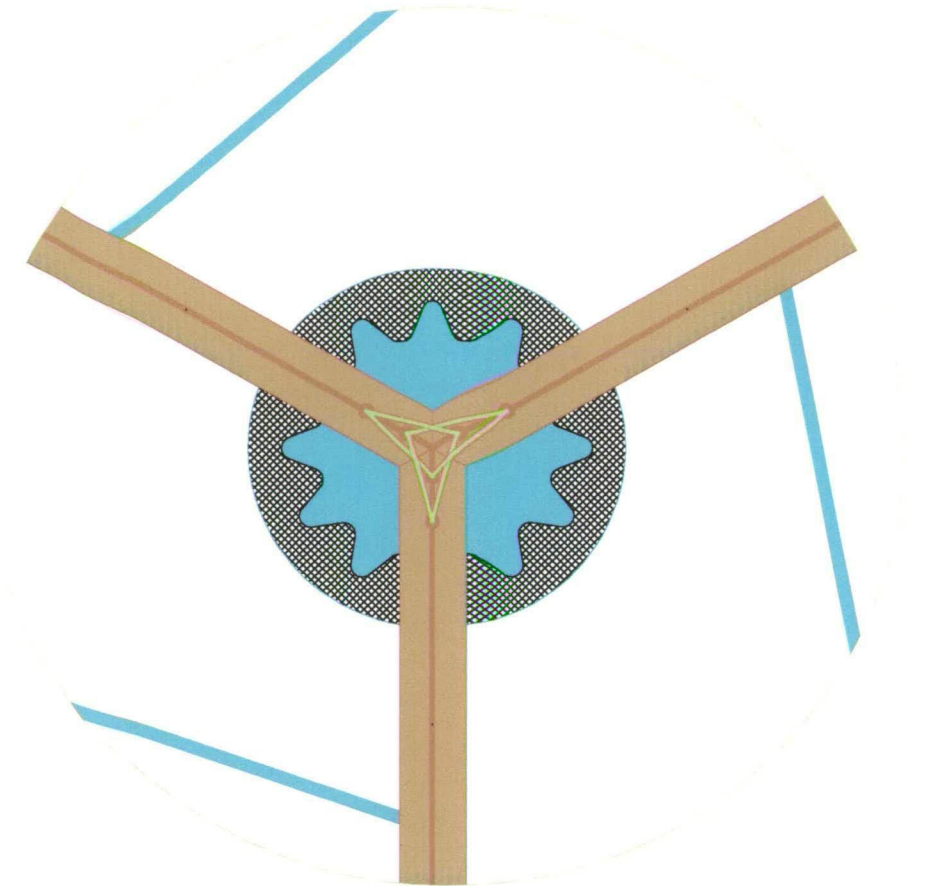
The ramifications of the design, combining the roof and ceiling as a singular stressed skin and allowing the materials' innate properties to dictate the curvature, have proved considerable. The concept of tent-like roof structures has been employed by a number of architects; the most prominent example was the design of the Munich

Olympic Stadiums by Günther Behnisch. There the suspended roofing material was comprised of three million square metres of shaped panels of transparent acrylic sheet bolted to a tensioned cable system and pole supports.

My idea was one thing but achieving it would be another! Given the budget restraints, the materials to be used offered the greatest challenge and many processes, inventions and re-inventions of components as well as engineering techniques had to be devised. It would have to be constructed by basic hand-work calling on all my experience and professional techniques in building skills. The design would have to meet the requirement of a



41 Roof components with lacing, rendered CAD drawing

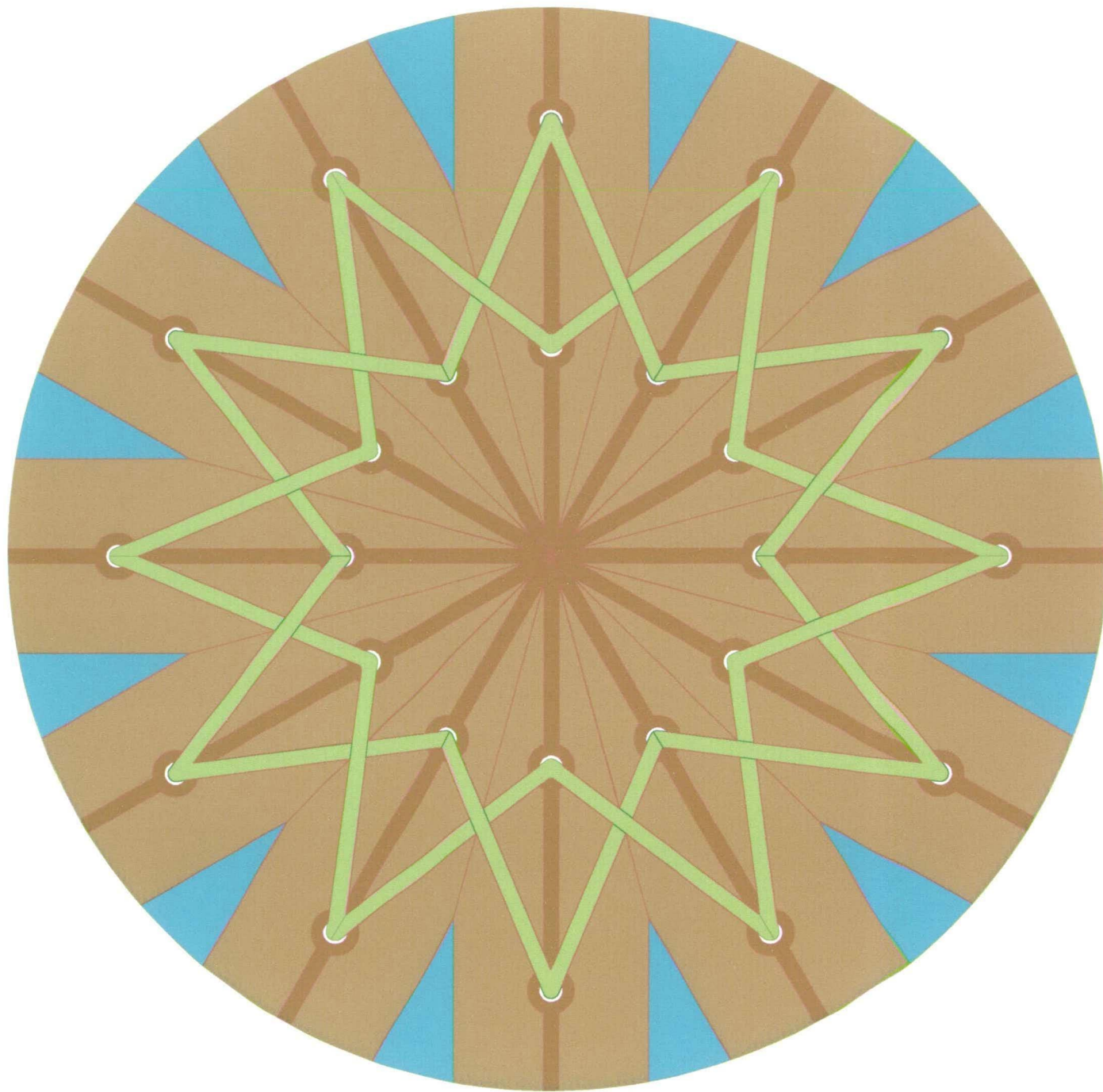


systematized form of construction that would allow for the construction of components in an on-site joinery workshop. At about this time my drawing / drafting of the Penrose rhomb and interlace work had moved to the computer and the use of CAD. During researching and doing the required engineering drawings for the supporting perimeter walls of the studio building, the idea of a triangulated wooden net (p21) seemed a feasible way to proceed: initially an overlay of a 900mm dimension triangular grid was drawn. A prototype (small section) made and tested, it proved too flexible and, due to the tri-point junction, unsound for fasteners and structural loadings. The scaling up of the grid to 1524mm to suit a double span of roof sheet and insertion

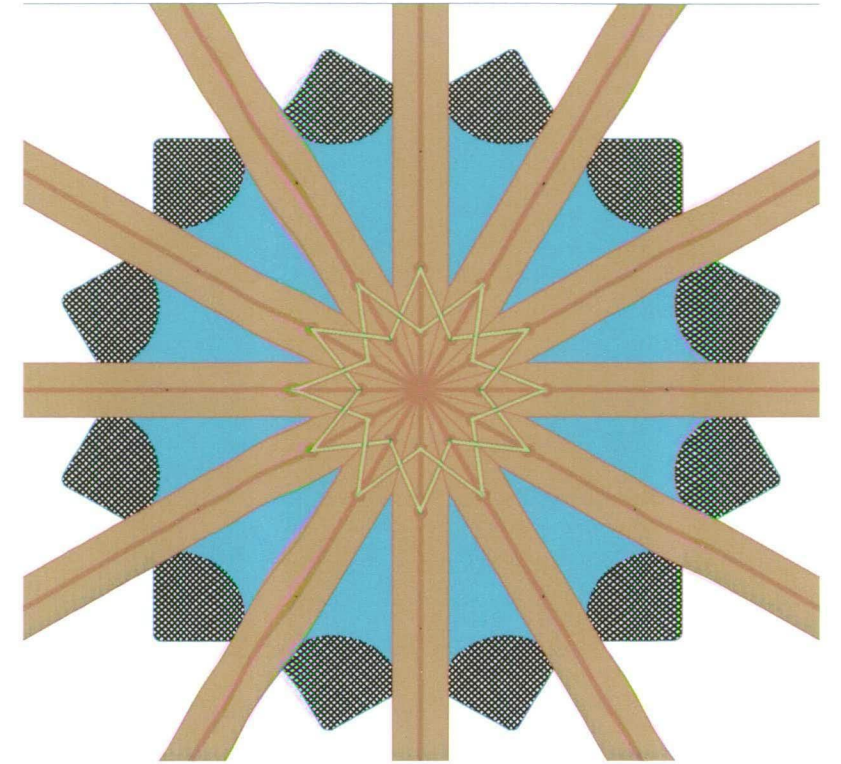
of an additional inner tri-lateral support offered a solution (pl.41). The doubling of the grid dimension immediately brought a variety of options for support and decorative solutions that would be both structural and appealing and fulfill the free spatial requirements of the ceiling surface. A 42mm x 42mm sectioned Oregon timber profile was machined. The set-up of holes, design of the lacing, plates and fastener methods were tested and chosen. A number of the two components were made and assembled for testing. The plate design and the lacing were adopted from the interlace pattern I had drawn earlier; it provided the perfect solution for the assembly of the component members,

solving the alignment and accurate set-up needs for hand assembly of the roof net (pl.42).

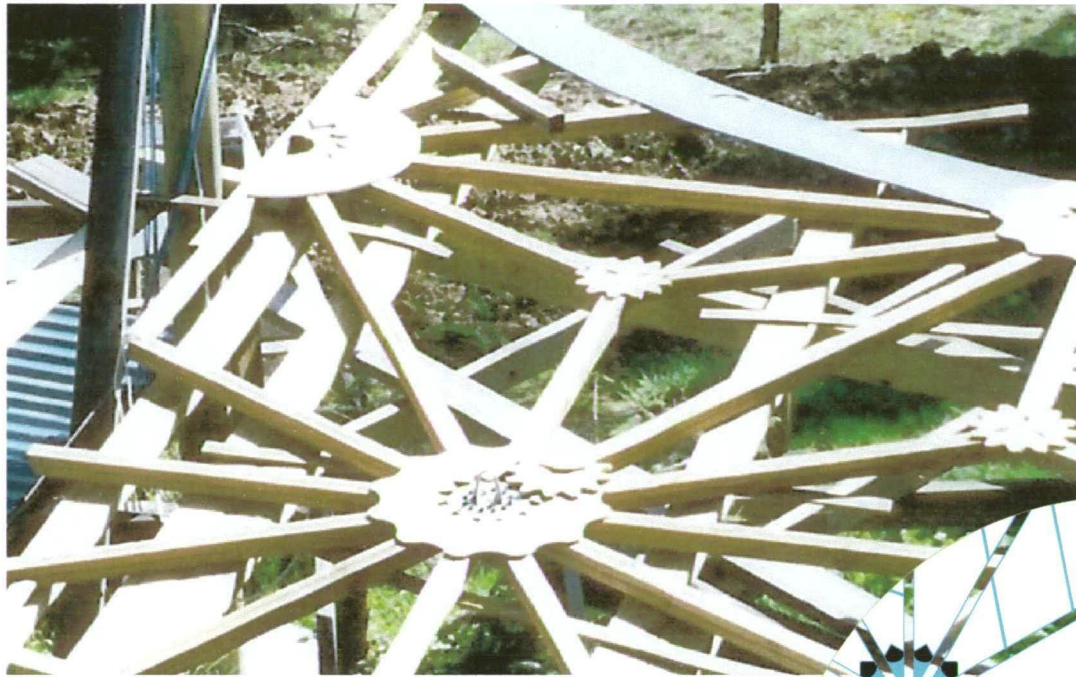
During this phase of design the need to choose suitable lightweight ceiling lining materials became paramount; the first inclination was to look for flexible fabric-like material but issues of longevity, mould, decay and general difficulties in installation eventually ruled out fabrics. The only remaining options were heavy plaster or a lighter thinner ply. It became apparent that if a ply were to be used the sheet sizes would be entirely unsuitable because of the edges requiring support. A more radical solution became necessary and considerable effort was put into developing a



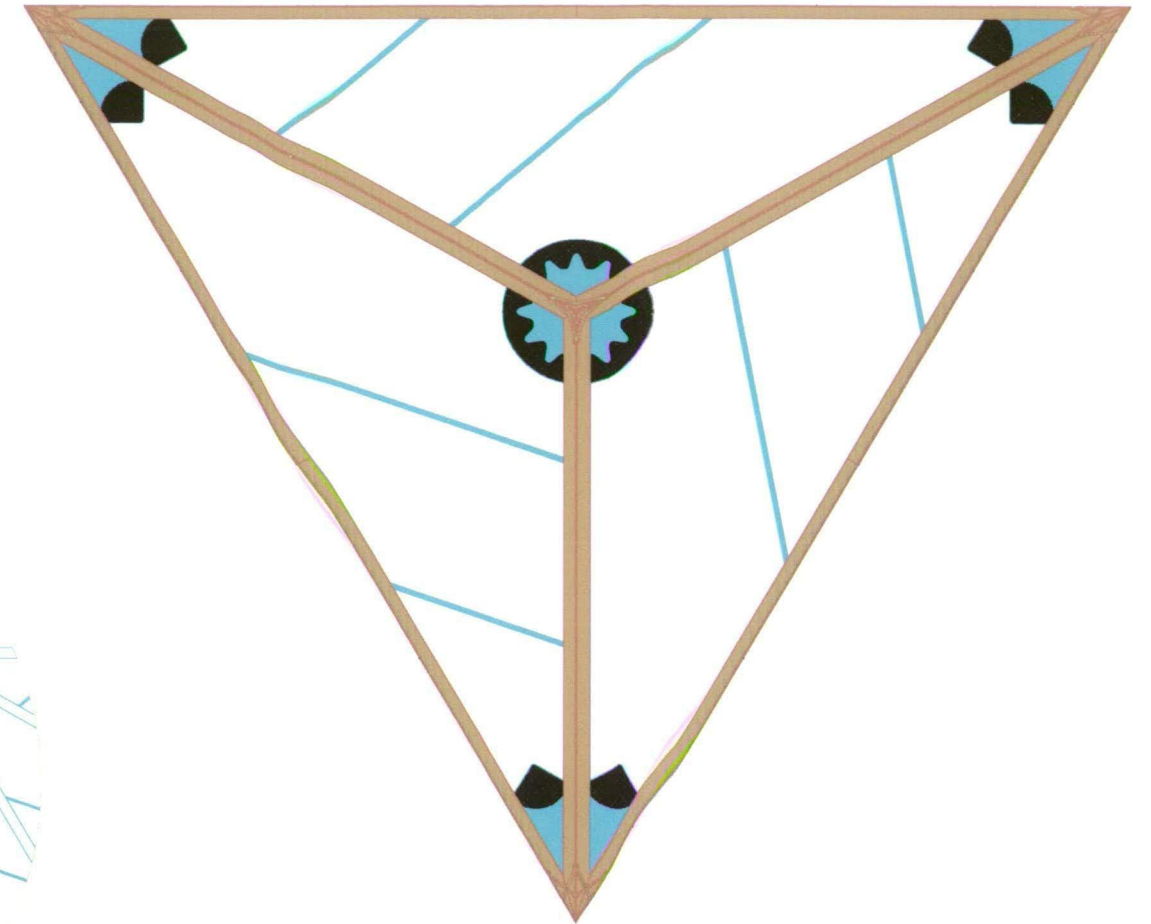
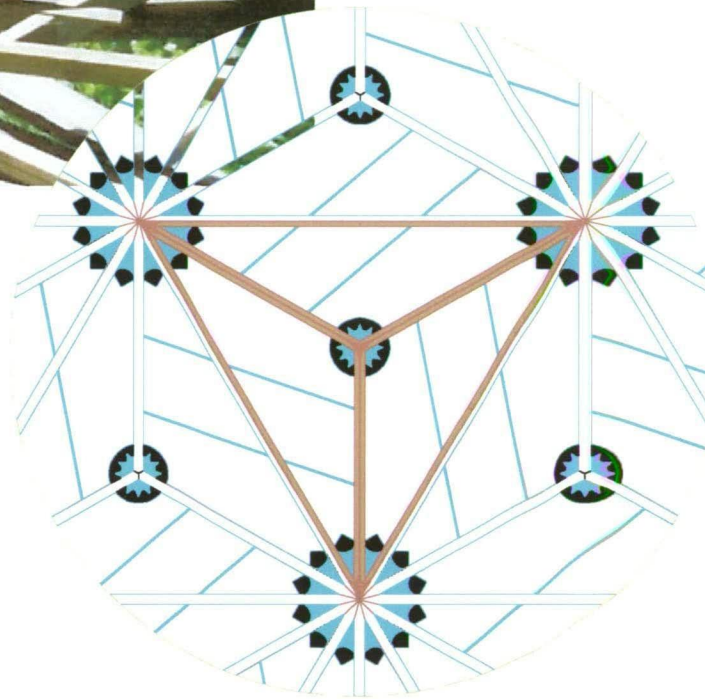
PL. 42 CAD rendered lacing design for twelve pointed junctions



Roof components with lacing of twelve and 3 junction rendered



44 Component assembly



43 Ceiling design drawing plan view from below

tiling solution that would fit all the requirements of decor, edge support, structural integrity and easy assembly. Again the solution came from a derivation of a geometric tiling / mirrored symmetrical shape which would adapt to manufacture and meet all needs (pl.43).

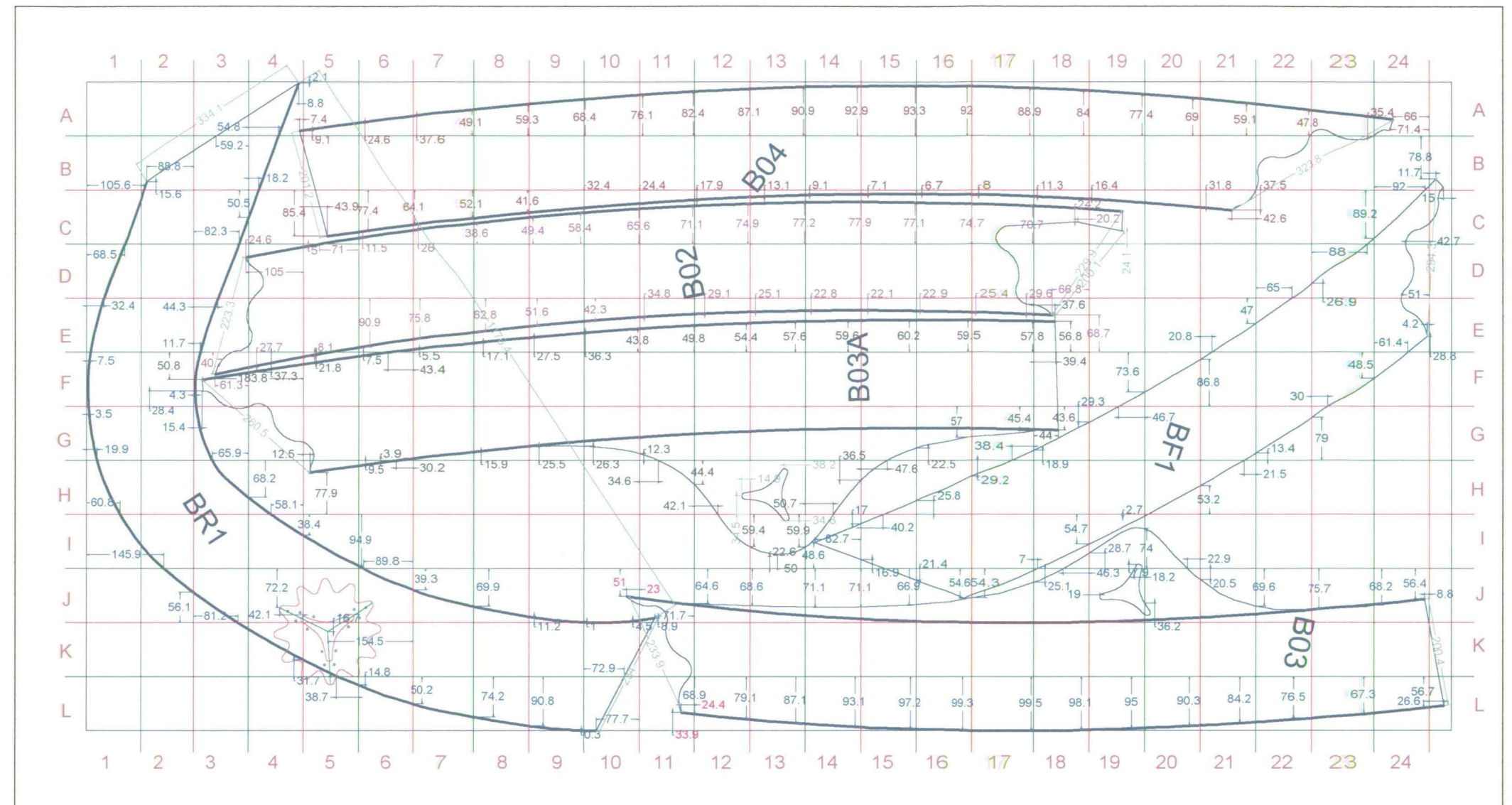
The development of the building's roof profile (edge line) was a direct response to the site, walls, support suspension and the resultant component junctions. When component members transverse a wall a termination of the member was made to allow the edge formation to be simplified. The

position of the ply edge was determined by exact measurement from the full sized CAD drawing (pl.45 p65). Then, transferred to the workshop and, utilising the accuracy of the individual component generated from the structured grid, measurements were made from the twelve points of the grid. All edge piece components were cut to exact dimensions from the drawing before assembly and numbered as to their respective sizes and positions in roof.

All design and profile of the roof edge was drawn in the computer and a full sized pattern system of plywood

members drawn out as paper templates and the plywood was shaped in the workshop. Production of the component members had to be systematized into a series of individual operations; each performed many hundreds of times in succession. Each operation was inter-dependant with the next from the very outset with the machining of the raw stock material on the table saw (pl.44). These repeated algorithmic sets of acts, determined and conditioned by grids and rules, produced the hundreds of component pieces that form the studio ceiling structural and decorative system. In deciding upon a geometric base for some form

Set out of plywood edge perimeter or roof (100mm squares) dimensions measured in computer drawing and transferred to grid with digital vernier caliper and curves faired with flexible batten for drawing curves. Cutting was all done with jigsaw and compass plane all pieces were cut before assembly, computer drawing is full size, five 2400 x 1200 sheets had similar drawings, allowing for accurate measurement.



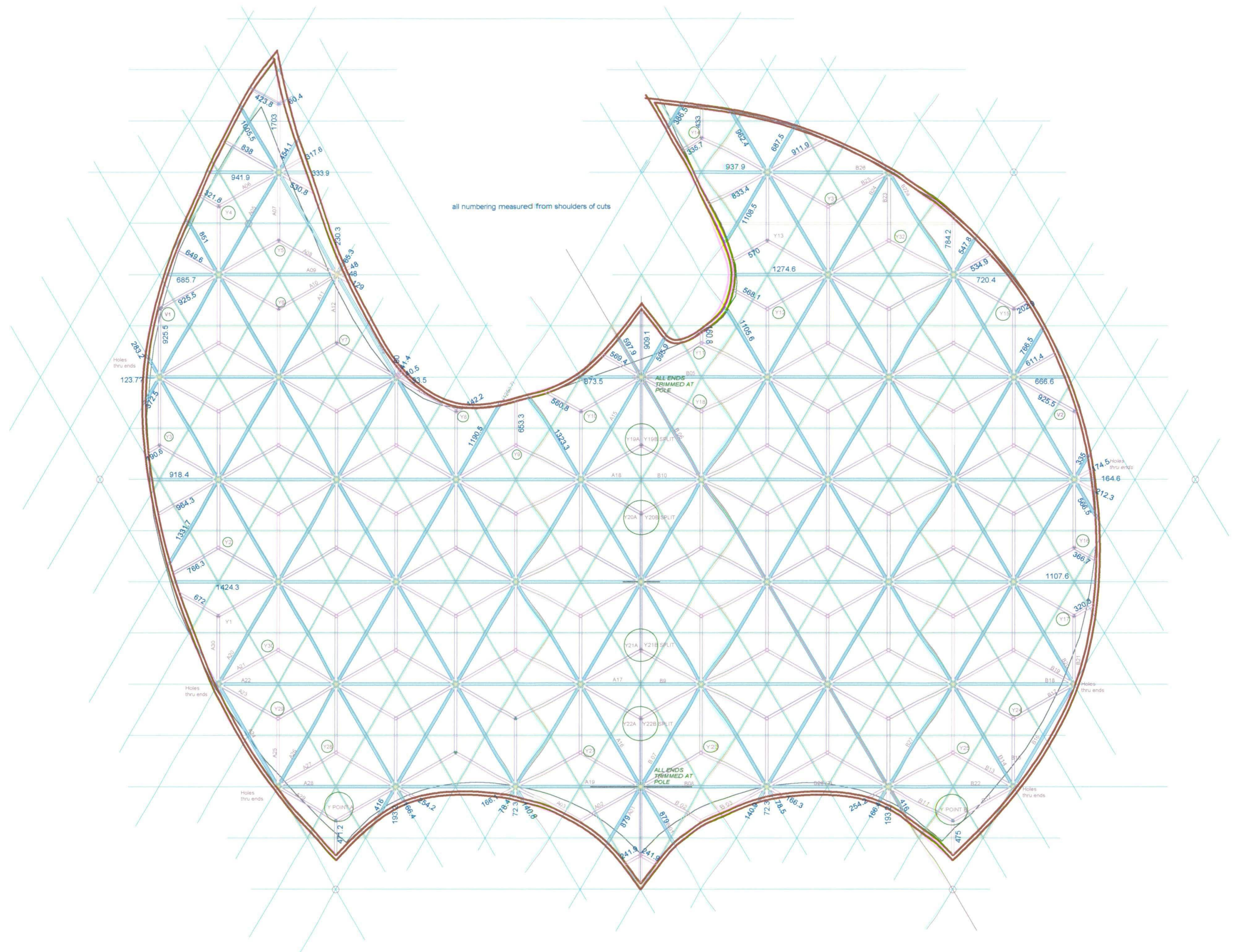
45 Drawing of edge profile components on plywood

of suspension system, the choices were initially quite open but, when engineering principles had to be involved, the decision was made to use the most elemental of grids as a starting point. The choice of an equilateral triangular grid provided the most elegant and practical solution (pl.46).⁴⁵

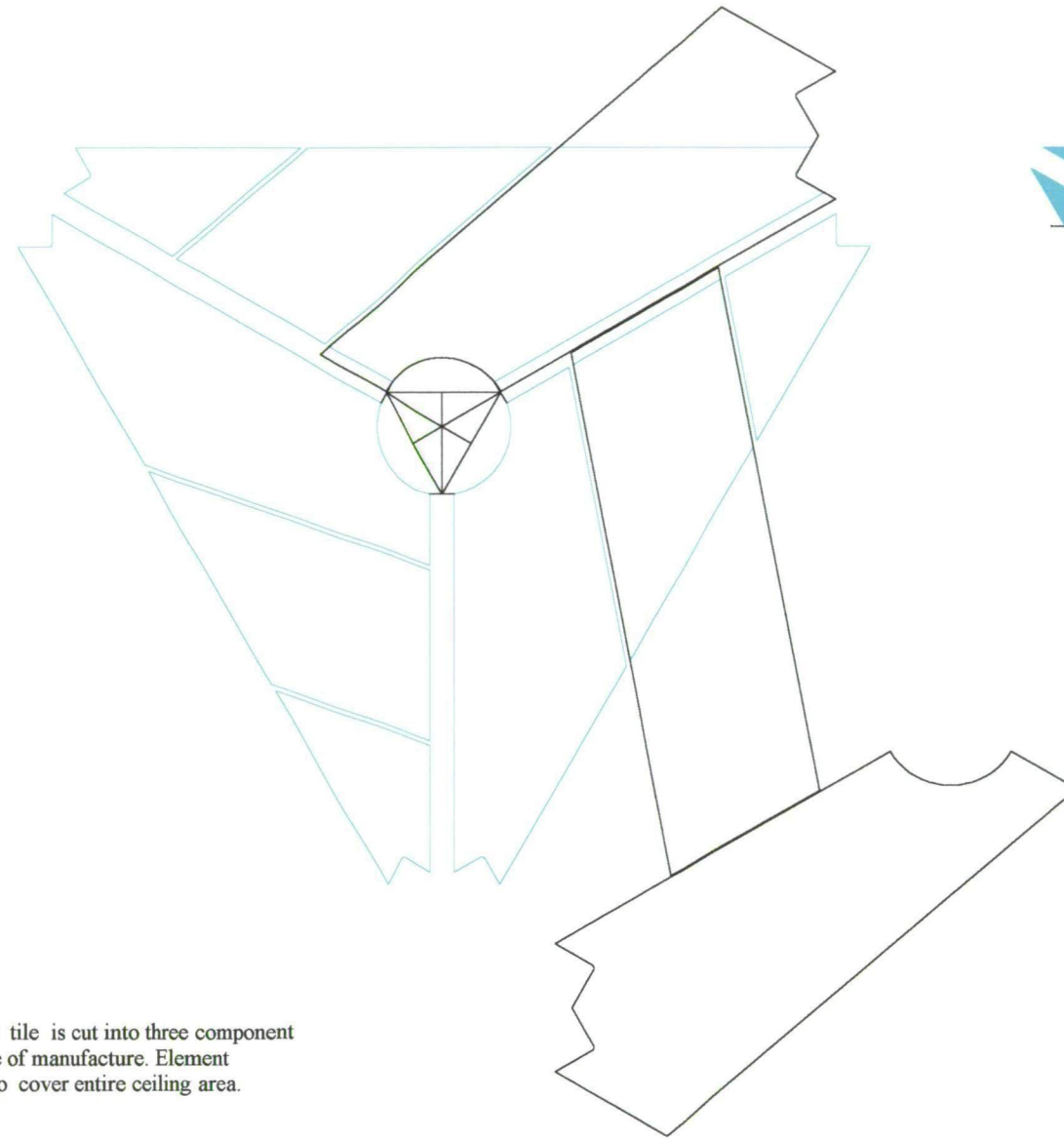
⁴⁵ The equilateral triangle, the hexagon and the square are the three primary plane shapes, which will independently fill a surface without leaving any gaps. Each shape has its own archetypal behaviour in terms of its self and, in different ways with its own matrix. Hexagons with their 'sixness' and six-sidedness can give rise to smaller or larger patterns by surrounding each point with a smaller similar figure so that each has a common edge with its neighbour; this implies an indefinitely small and large growth system. The triangle also has many ways of reflecting itself and reproducing itself in a similar manner. It also creates further triangles by forming a link between opposite points of a pair, so that a pattern of six triangles in hexagonal form has two such larger triangles within it.

For details of some of the twenty five thousand individual operations performed to make the components for the wooden net see Appendix I, (*Compilation of Actions and Procedures Employed in Fabricating the Ceiling Design System*).

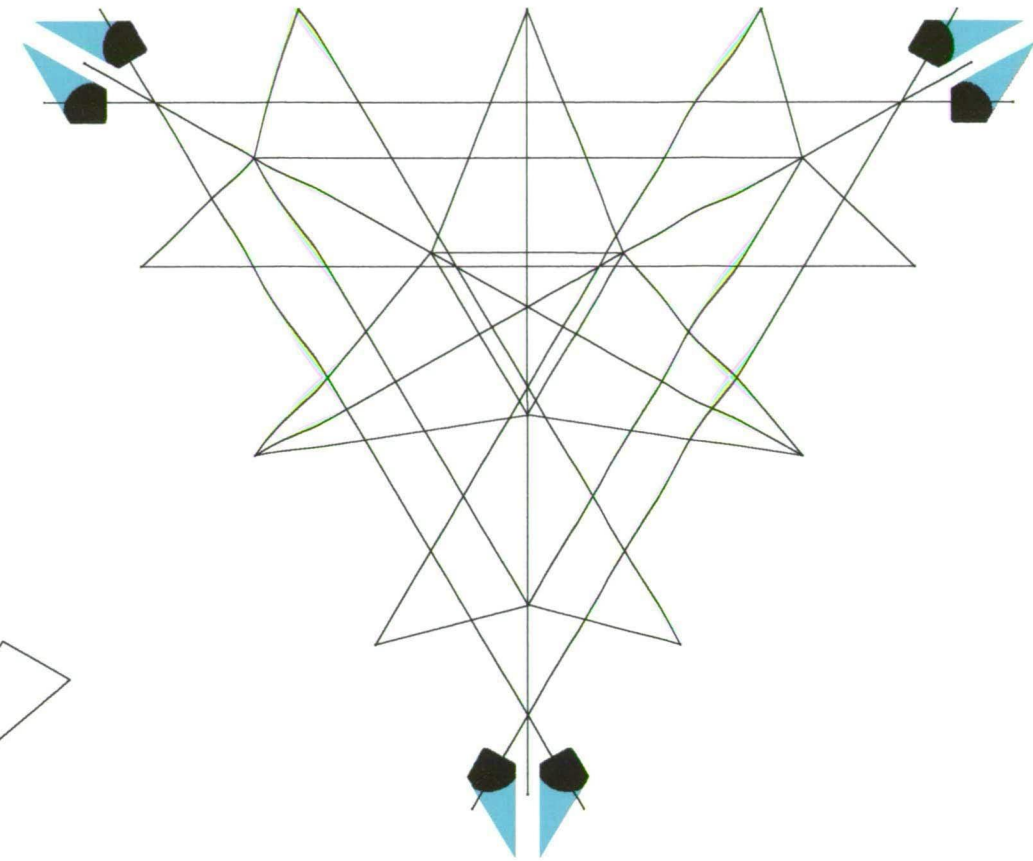
The design drawings and the engineering of this system are all completed and documented but the realisation of the full sized prototype is in a state of ongoing construction, requiring many hundreds of hours of additional work. The work on this part of the project has been slowed by inclement weather experienced in the early construction phase, recent very high winds and the building of the now completed 'Purdie House' including the Volumetric series.



46 Roof Component Grid Measurement for edge profile



47 Ceiling design tile is cut into three component pieces for ease of manufacture. Element tiles are able to cover entire ceiling area.



Suspension Grid lines of hole array

*Sifting order from randomness - from the very beginning has been the driving force of life...*⁴⁶

The inclusion of the ceiling system within this project has been as an experimental prototype which when completed will be a fully functional art work-space and exhibition area. Furthermore, as it is adjacent to my wood workshop, it will operate as a test bed for work, where works can be suspended in the same spatial relationships as modelled in

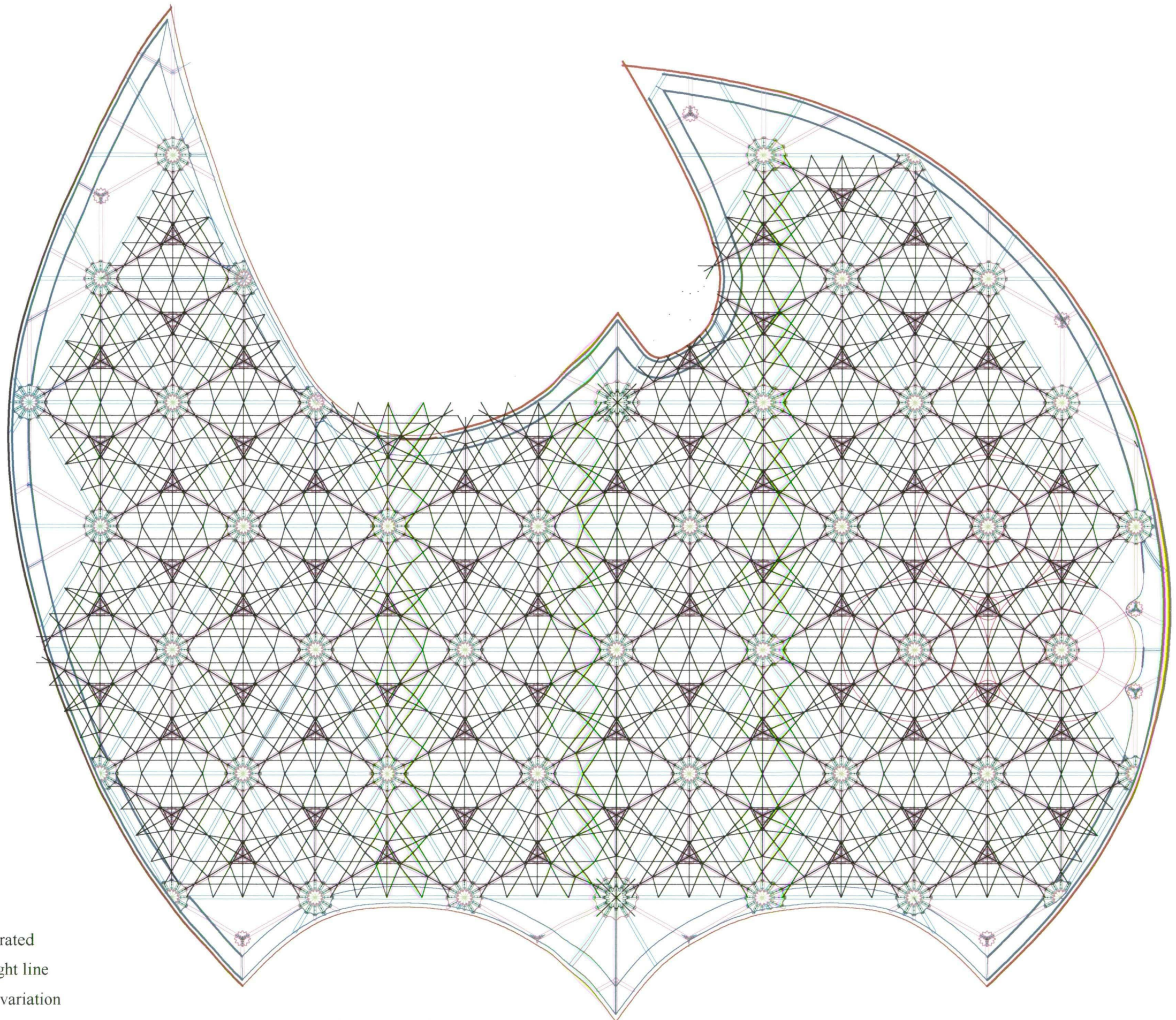
the computer. I realised that conceptual modelling of new works using the computer would benefit greatly from a grid system of mounting points. Three holes were drilled to form a T shaped holes to allow for nylon or stainless steel lines to be inserted and pinned. The positions were spaced to a systematically designed grid of equilateral triangles to form a multi-purpose suspension point array system within the visible structural components of the ceiling/roof system, incorporating both a decorative and a functional role (pl.47).

Also the within the ceiling roof construction is a wiring loom comprising a series of eleven circuits of twelve volt

lighting providing twenty six connection points for suspended lighting

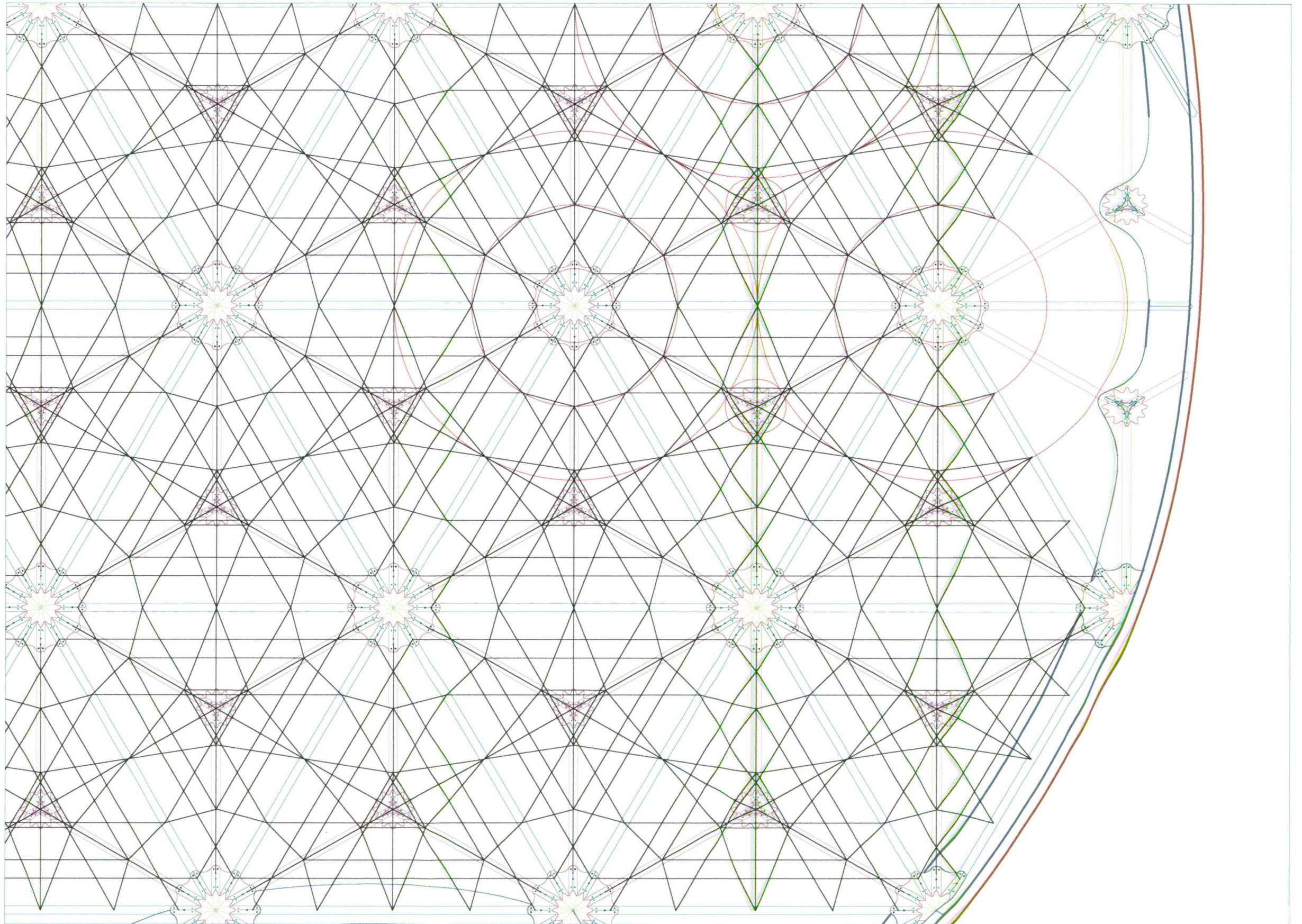
Central to the function of this building is its 'virtual' model in the computer. The concepts of future works can be drawn in two dimensions first, in the manner of interlace or tilings and be given three-dimensional form, be modelled and worked on in the CAD environment. The computer model of the work (Latt-tile or other modules) can be floated or placed within the 'virtual' building model. It can then be manipulated or viewed, lighting settings can be

⁴⁶ Johnson George *Fire in the Mind: Science, Faith and the Search for Order* Viking, London 1996 p.7

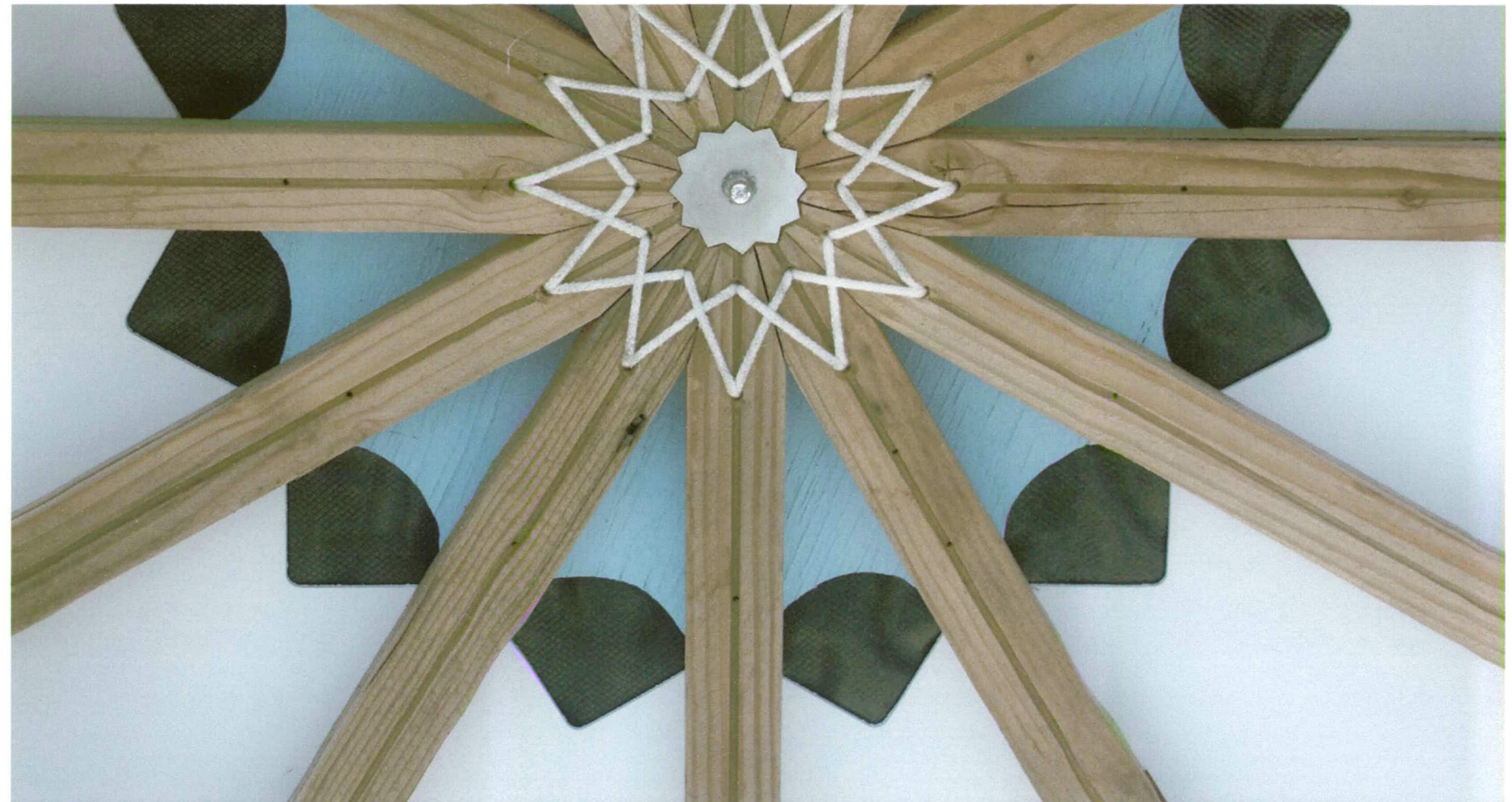


Roof suspension grid illustrated is a primary layout of straight line connection points. Infinite variation of the grid is possible.

PL.48 Plan view of total suspension point web (black line)



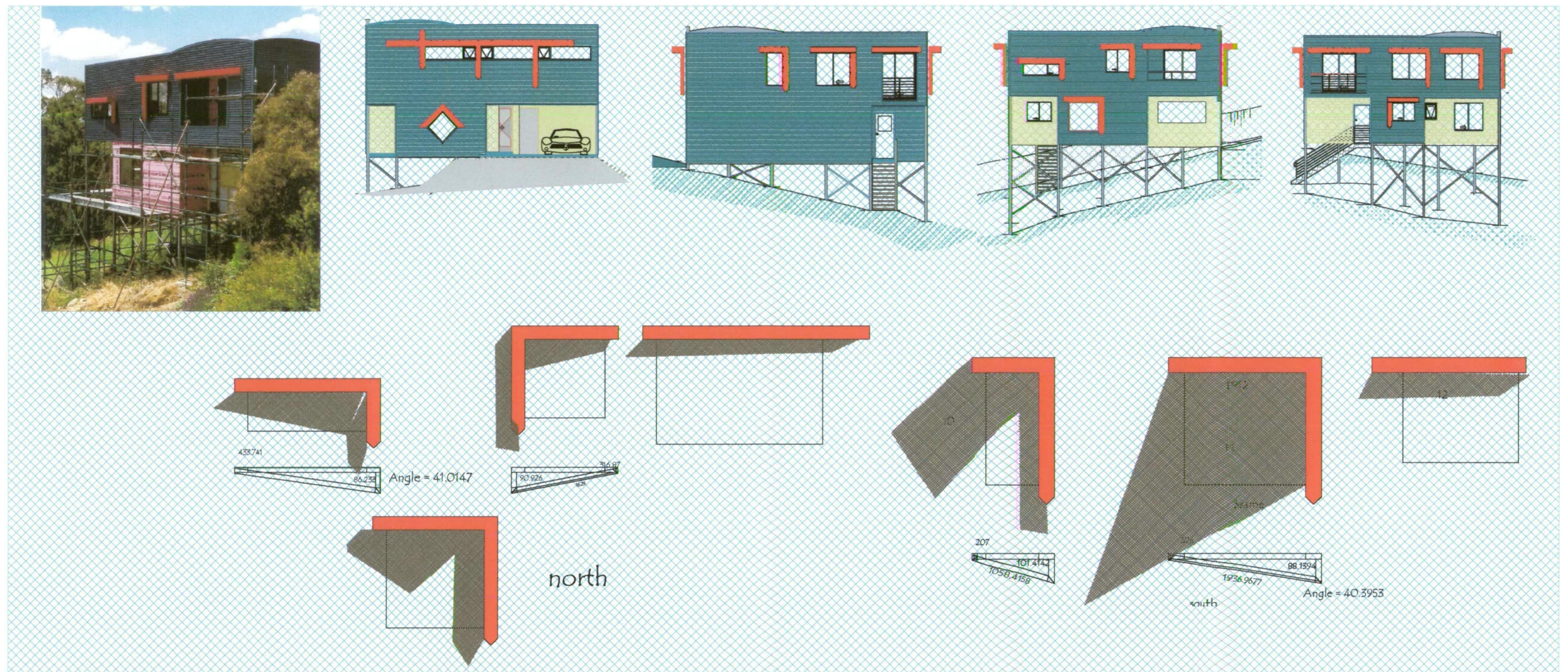
49 Close up of suspension grid: shows lines of connection to suspension points



50 Detail of roof wooden components and decorative lacing and suspension points

applied and shadows noted. Moving ‘fly-throughs’ will be able to be made, drawings and images can be printed and the model work, if it is to be suspended, can have attachment points selected in plan view and individual lines drawn to the ceiling mounting points above. The subsequent models can be taken to full size prototypes in the workshop and the individual components transferred to

the gallery for suspension beneath the ceiling. Using a list of all the co-ordinates’ lengths of lines and heights or angles it is then a simple matter to install the work using the components and suspension system to replicate the original virtual model.



51 Shadow details on elevations of Purdie House 2004

SYSTEM 3 – VOLUMETRIC SERIES

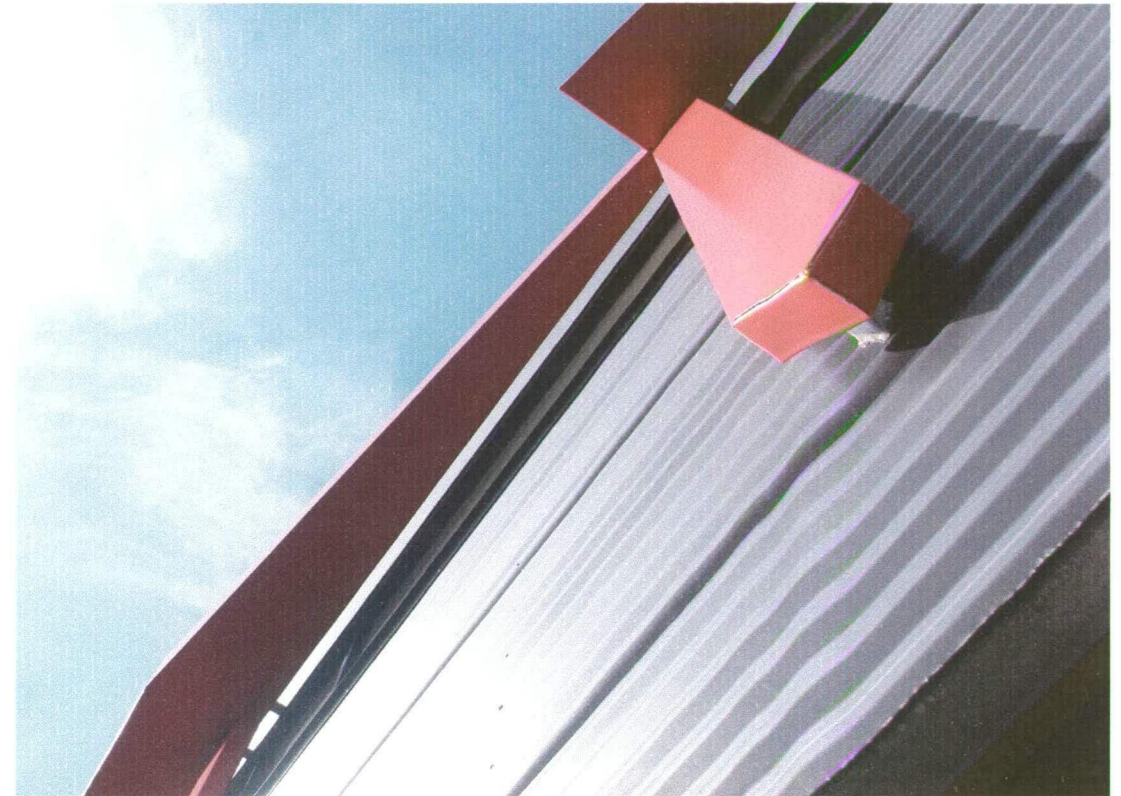
The incorporation of research, studio/workshop production and architectural design has seen the recent realization of a series of large modules or decorative elements: a system of linear formed volumetric entities employing processes and the geometric generative techniques developed throughout the project. The original design drawing of the volumetric series was a direct visual response to an image created earlier on drafting film, a coloured painted section of

interlace pathway, a section of recursive loop (pl.10a p15). This piece was done while in the process of experimenting with transparent colour effects and the visual effect of the interlace elements set against each other in differing colour combinations. The volumetric series forms are a derivation of the Solomon 'Bird' Latt-tile work and Solomon Star series work. The creative use of reflected coloured shadows, as in the Latt-tile clusters and the Solomon series of modules, has been

carried through to this series. The geometric formation of the units' elements has a core logic in $\sqrt{2}$ harmonic ratio, offering each a systematic relationship. I took the constructive geometric line drawings through a manipulation process of extraction and reformation, re-drawing and re-working, extracting elements. The resultant elements form the starting point for the creative development of new tri-dimensional, isomorphic objects.



52 Volume Series Western Elevation 2004



53 Volume Series Western Elevation 2004

During the process of creating the working drawings for the Purdie Street house elevations, choices as to positioning the elements had to be calculated to include the shadow projections (pl.51 p71), together with individual component dimensions, placement and mounting systems, all of which required considerable engineering. The choice of material for construction at this design stage was a wooden framework clad with render-board and a rolled on application of textured render in a deep red coloured finish.

During the construction phase of the building the mounting system for the modules had to be re-engineered. The original design was too heavy and had significant problems

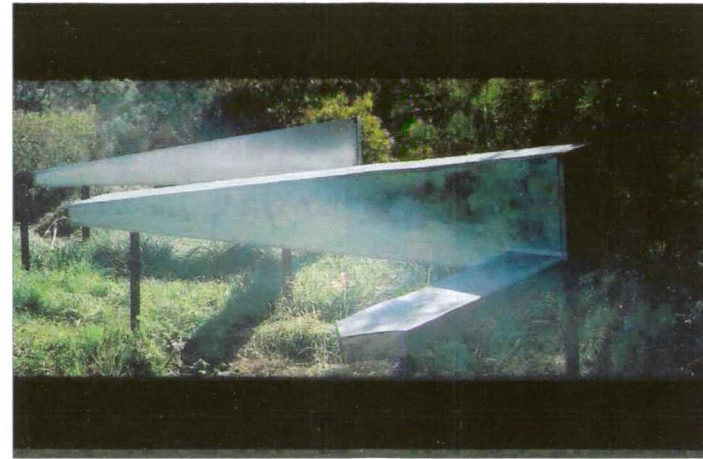
regarding endurance in the exposed position (10 metres) above ground on a north faced steel wall. Therefore a search for a more suitable construction system and material for the forms had to be undertaken. The major breakthrough with the Volumetric series was the discovery and choice of BHP steel material 'Galvaspan' 'C-section' purlin that is rolled in continuous lengths. The individual modules were fabricated off site in my studio workshop. Each module has had its linear perimeter length of steel purlin cut to measure and marked using trigonometry and the full sized computer drawings. I used the dimensional accuracy of CAD to enable the defining of the complex angles that were required to be marked out for the cutting

and removal of sections of metal that would allow the material to be bent and folded into shape for welding. Transferring the measurements from the computer was aided by the use of a digital vernier calliper that could be set to the accuracy of the drawing. The triangulation of the required complex angles, such as 59.75° for example, did not need protractors for marking since each angle was measured with an engineering square allowing easy transfer from the computer drawings. I cut and shaped the material by hand using an angle grinder.

Jigs were made to help the folding of the steel and methods of scoring the inner surface developed to allow the material



Fabrication of steel purlin for Volumetric series



Ready for etch primer coating



Enamel painting of Volumetric series



Etch primer coated modules



Large front elevation module ready to paint

54 Volumetric Series Fabrication of Steel forms 2003

to fold at an acute angle. Each module needed a considerable amount of welding, grinding and polishing to get it to a stage ready to paint. Flat galvanised sheet steel was used to close in the top surfaces. Neoprene sealant/ glue was applied together with a thousand rivets inserted into the fifteen modules during the fabrication (pl.53). Due to the unconventional building methods needed for these modules all the fabrication, finishing was done by myself.

Considerable testing of suitable products for the painting system was required because *Galvaspan* C-section purlin

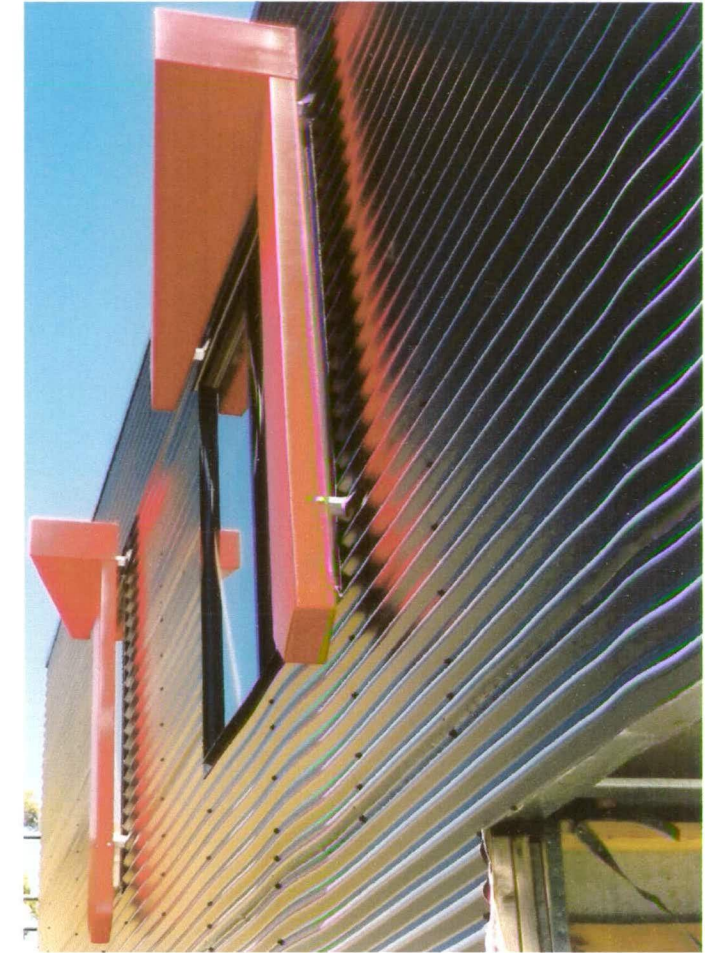
has very limited surface adhesion properties for conventional paint systems. The material did have many beneficial properties assisting the mounting and fabrication process, together with several intrinsic properties that I studied and tested in regard to light refraction from both the external face and the internal surface. When coloured or left natural the C form has the capacity to trap and multiply the intensity of light when in a suitable position (harmonic relationship) for alignment of the light source and wall surface. It intensifies the natural effect of reflection. In

planning future works *Galvaspan* C-section purlin will be a core material for linear, large sculpture works.

The Volumetric Series involved the suspension of shaped singular modules. These forms are fifteen large painted steel units that are attached and suspended 70mm off the planar corrugated steel walls of a 10.4metre cube-form residential building. I have designed and built this building to present a stage-like physical façade as a support for the appliqué of functional decorative three-dimensional forms



55 Volumetric Series South Elevation 2004



56 South Elevation 10-am showing reflections

of linear elements⁴⁷. The Volumetric elements have been superimposed as mark, gesture, or drawn element, applied hovering over the facade of the building: floating object over structure as drawing. The creative use of reflected coloured shadows, as in the Latt-tile clusters and the Solomon series of modules, has extended the previously developed techniques and kinetic visual properties into the volumetric series of work. This has been a key outcome in its practical application of the projects' developed concepts.

The orientation of the cube-form structure, location, height and exposure to the sun, and the resultant observer's viewpoint offers an ever-changing, visually active architectural surface or façade (pl. 54-55). The suspension off the corrugated steel surface of these particular shaped forms, together with the combined differing effects of cloud, sunlight and weather, activate a kinetic display of moving shadows and multiple coloured reflections on the building's 'Mountain Blue' steel façade.

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⁴⁷ The geometric formation of the unit's elements has core logic in $\sqrt{2}$ harmonic ratio, offering each a systematic relationship.

CHAPTER FOUR: CONCLUSION

When I started this project part-time some years ago, I envisaged the outcome would be discrete artworks that would be either installed in interiors or be incorporated into an exterior venue. The research itself and the difficulties in finding appropriate locations for installation of works has directed the project towards an outcome of systems with a potential for applied research and use. The project has seen the systematic generation of methods and design tools together with unique methodologies that can be adapted to aid in the ongoing design process. The computer generated

drawings developed during the research form a store of templates available for adaptation depending on the requirements of the application. CAD software applications enable the creation of full size tri-dimensional models that can be rendered with surface effects and simulated in photo-realistic imagery complete with lighting and shadow. The move to strategic adaptive use of CAD manipulation capabilities has given me new ways of conceptualising and developing methods for the creation of the underpinning linear based constructive drawing frameworks. Throughout this project I have developed virtual templates and models that provide rapidly formed but coherent aids to the creation

of new design elements and virtual product that have harmonic form and relational logic. These templates and models are now ready for commercial application.

As quoted elsewhere, Jane Pavitt states...*There are parallels between the use of CAD and the idea of craft practice...*

The systematic fusion of CAD capabilities and processes with my preceding historical trade/craft drafting and carpentry skills has aided the application of the three systems' project outcomes.

The three systems that have been core to this project each have individual applications. Latt-tile modules can be scaled to any size. The knot design is one that suits the rhomb form and is adaptable to other shapes. It has provided a vehicle for the initial development of the tiling system. However, the principles of the system are able to be adapted endlessly using the principles and properties discovered during this project. The geometry of the rhombs can be changed and elements of the Latt-tile, the ribbon-like pathway, can be extruded, bent or folded to follow any tri-dimensional form.

The working drawings I produced during the design and development of the Latt-tile, the interlace, the Bird series, the roof/ceiling system and the Volumetric series can be seen as demonstrations of process when viewed on the gallery wall.

System One: My original concept was that Latt-tiles of any scale could be used to redesign, reinvigorate or decorate tired building façade, curtain wall or fenestration. The Latt-tiles can be manufacture from any of several materials that have a stable surface such as custom-wood, ply wood, ceramics, metal, glass, acrylic sheet, polystyrene or concrete. Latt-tiles made from any of these substrates present an ideal vehicle for the use of *Axolotl* metal

finishes. Mounting Latt-tiles to advantage their design demands a suitable fixing technique and various systems have been developed and are adaptable to the requirements of scale. They can be added to existing building curtain walling and offer multi-purpose systems in the arena of architectural façade. The concept of a Latt-tile system cascading in a simulated 'free fall' array down the side of a building such as the Marine Board Building, Hobart, offers an exciting and revitalizing way to enliven a city streetscape. Latt-tile arrays could be scaled and re-configured and the surface treatment could include the use of Photo-Voltaic technology to allow for the operation of a PV cell array – integrated solar power generators as part of

a system of ornament. This multiple application could sustain and pay back the cost over a period of time.

System Two: The principle of the suspension points within the decorative ceiling structure of Studio 33C could be applied within other buildings' engineered roof/ceiling design. This would enable the interior space to be used for changing and adaptive applications with moveable suspended objects or decorative screens of Latt-tiles. In addition the interior space could be divided by suspending partition walling, signage and/or lighting. A role for this type of application out-of-doors could be developed by the use of a linear steel framework which rises from the ground, arches up over a public space in a tracery of steel

engineered to be self-supporting and able to incorporate an articulated, extendable and adaptive roof system. Left open, as in the openwork of Latt-tiles, it will simply define a public space with filtered light and shadow. The Latt-tile concept could be applied to a range of architectural situations. In Hobart, as a further example, there is the possibility of spanning an area such as the current Princes Street Pier site, to define a multi-functional public space with a spanning extruded steel lattice geometric form.

System Three: The Purdie Street project has resulted in the strategic development and design of decorative systems that can operate as independent entities, new spatial units,

or modular systems that can be part of an adaptive system of architectural ornament.

I believe that the strategic application of hidden and secretive geometric knowledge together with the new methodologies and concepts discovered throughout the project, will offer a new capability for the generation of architectural ornament and artworks, bringing with it a *New Craft Practice* to the three-dimensional computer modelling design environment.

** ** *

APPENDIX I

Compilation of actions and procedures employed in Fabricating the components of the ceiling design:

The requirement of a system of construction be developed that would allow for all the construction to be componentized and be able to be made in on site joinery workshop

The idea of a triangulated wooden net seemed a feasible way to proceed, initially an overlay of a 900mm dimension triangular grid.

A prototype (small section) made and tested, it proved too flexible and due to the tri- point junction unsound for fasteners, and structural loadings.

The doubling of the grid dimension immediately brought a variety of options for support and decorative solutions that would be both structural and appealing and fulfilling the free spatial requirements of the ceiling surface.

The larger triangle would allow the inclusion of an additional layer of pattern by the division or 120° y's.

A 42mm x 42mm sectioned Oregon profile was machined and set up of holes, lacing, plates, fastener methods were tested, and chosen.

The plate design, use of 7mm ply wood and the cutting of pattern

The lacing was adopted from the interlace pattern drawn earlier, it provided the perfect solution for the assembly of the component members, solving the alignment and accurate set up needs.

The plate design, and the lacing was adopted from the interlace pattern I had drawn earlier. It provided the perfect solution for the assembly of the component members, solving the alignment and accurate set up needs.

- The need of suitable lightweight ceiling lining materials became paramount, the first inclination was to look flexible fabric-like material.

- Design of the ceiling lining tiles

Options heavy plaster or a lighter thinner ply, it became e apparent that if a ply was to be used the sheet sizes would be entirely unsuitable because of the edges requiring support. A more radical solution became necessary considerable effort in developing a tiling solution that would fit all the requirements of decor, edge support, structural integrity, and easy assembly, was undertaken.

The buildings roof profile (edge line) of perimeter was a direct response to the site, walls, support suspension and the resultant / roof member component junctions.

When Grid members transverse a wall a termination the member is made to dimensions taken directly from computer for work on the bench individuals allowed the edge formation to be simplified.

The measuring of the edge pieces from centres of the twelve point junctions allowed the computer drawing in full size to be applied directly, in the formation of shape of roof.

All design and profile of the roof edge was drawn in computer and a full sized pattern system of plywood members drawn out as shown, shaped in the work shop, squaring up of sheets

Production of the component members had to systematised into series of individual operations each performed many hundreds of times in succession. Each operation was interdependant on the next, right from the out set; the machining of the raw stock material on the table saw. The following is a list of operations

Fabrication of the stock selected from recycled Oregon timber 200x50mm size planks

200m in 6 metre lengths docked on site for transport into 1.9m and 2.7m etc. lengths

First operation was to grade stock quality into A, B and C pile

Then select lengths removing waste knots (cutting out as many defects as possible) whilst squaring up ends and obtaining billets for stock milling

35 lengths for long pieces and 70 for short

Each of the 105 pieces is ripped on table saw 3 times to provide the stock pieces 410 in total

These billets were to provide for long members $130 \times 1.8\text{m} = 234$ lineal metres

short members $280 \times 1.05\text{m} = 294$ lineal metres

The machining of these was carried out on the table saw using multiple passes through the saw to provide straightened and widthed pieces (each piece is oriented so that the hollow side of the bend is against the fence to aid in straightening the outside).

Each of the 410 component pieces were passed through saw (528 metres fed through saw for one pass)

KEY: figure in red are number of actions
 figures in blue are saw end cuts or milling actions

1 paralleling pass to within 2mm 410×2 (Repeated.2)

(Stock thickness is 45 mm at this stage)

Each piece is passed through on 90 degrees again to square up 410
x 3

Two faces are skim cut to 43 mm square 820×5

Best faces are selected each time

And repeated to 43.5 mm finished size 820×7

This was repeated so all faces had been freshly skimmed 820×9

A parallel cut 19mm from each face was cut to ensure a 4mm wide centre line groove (which has played a major part in overall assembly) depth of 2.8mm.

Each of 410 components has 4 faces x 2 passes 820

3280 passes through saw giving a running lineal metreage of 528m each pass

3289 sawing operations (tot: 1,736,592m) @ 5 sec per pass through saw giving a cutting speed of 12 metres per minute should take 2,412 hrs or 301 x 8 hr days (but it didn't)

End of table saw ripping

Docking

Each end of the 410 pieces was selected to cut out knots and defects
820

Best end selected and each long and shorter piece cut to stop block
410

Accurate length of 1758mm and 1015mm

Systematic counting and placement of each piece of stock

Each component piece was stacked in order to track every operation and facilitate handling. Stacking was ordered so that the working face mark was always upper. Stacking was monitored for quality, consistency, colour, straightness, and numbers.

Point cutting for 12 point junctions and 3 point junctions

Ensuring main face kept up at all times each long piece and one end of the shorter receives a 30° point. A jig was made to assist the drop sawing operation, a test piece cut to trial a fit of twelve pieces intersecting. First cut was so accurate no adjustment was necessary, each point was cut leaving a 1mm wide end so as to facilitate stop block processing of all hole drilling operations.

The 540 - 30° points were cut from left side only flipping stock for opposite angle. Operations $\times 2$ for each end point = 1080

280 shorter components with 120° points $\times 2 = 560$

Drilling

After points, drill press set up with stop blocks for the first set of 5mm dia. holes for the lacing: two holes for each of the 30° points and 2 closer spaced holes for the shorter 120° ends $410 \times 4 = 1640$

Each hole countersunk 2mm deep for relief of lacing at edge of hole: both faces $2 \times 1640 = 3280$

Hanging point holes set up @ 2mm dia 'T' shape formed by drilling to a depth of 21mm from two sides and the main face to provide attachment point for looped wire or nylon line

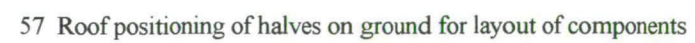
130 long members have 5 sets of suspension points $3 \times 5 \times 130 = 1950$

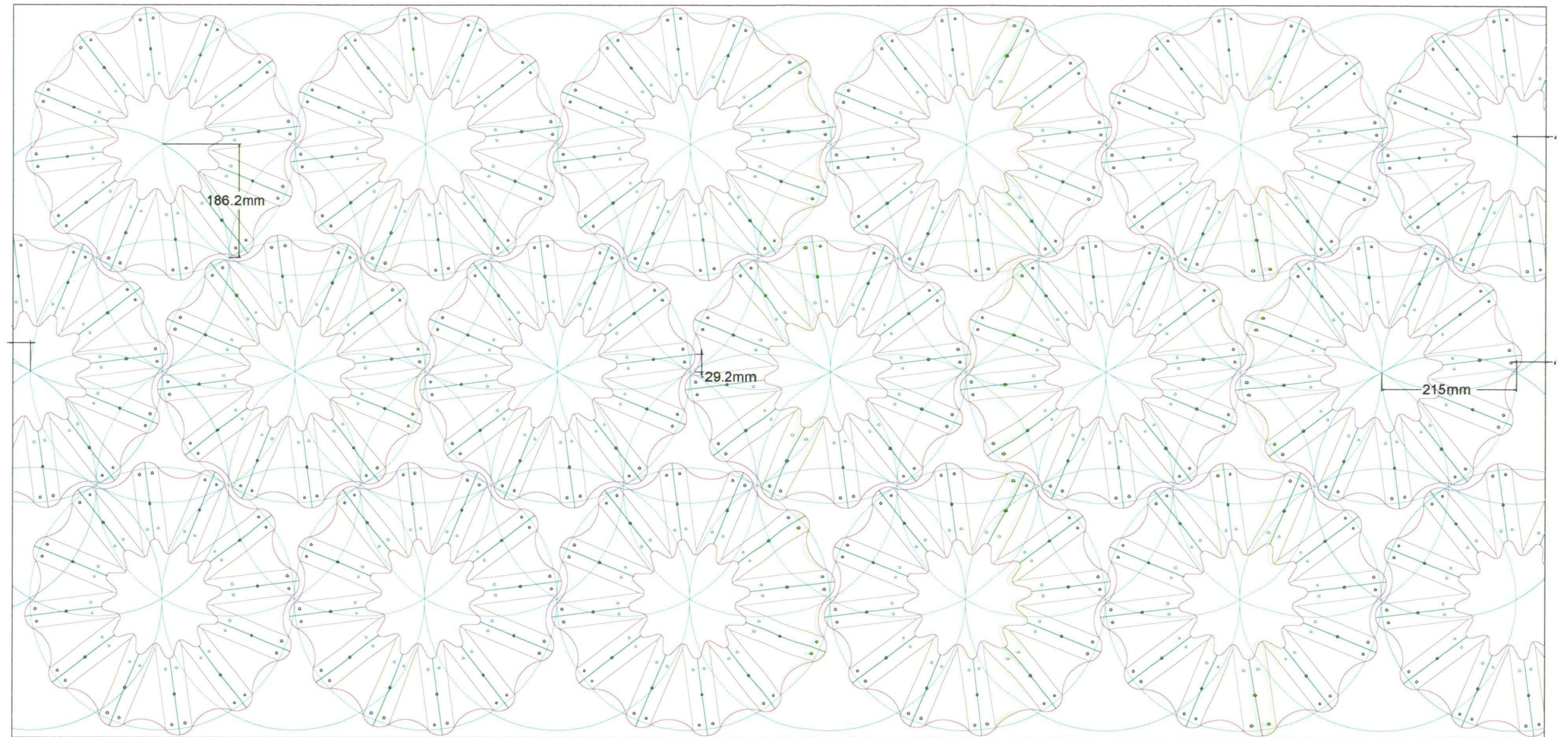
280 shorter members have 3 sets suspension points $3 \times 3 \times 280 = 2520$

Total: 15,539 operations.

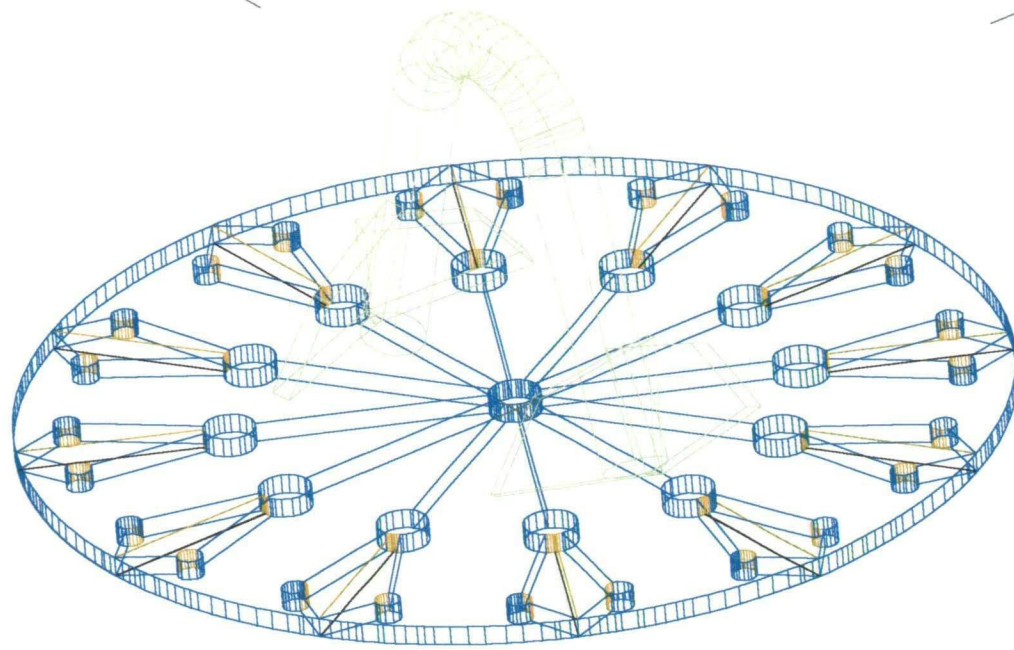
The design outcome was a tent-like structural system that would be both the roof and ceiling combined as a singular, stressed skin, using the natural bending / droop of the material's properties to dictate the curvature and free form lines of the roof. In deciding upon a geometric base for some form of suspension system, the choices were quite open initially, but when engineering principles had to be involved the decision was made to use the most elemental of grids as a starting point. The choice of an equilateral triangular grid provided the most elegant and practical solution.⁴⁸

⁴⁸ The equilateral triangle, the hexagon and the square are the three primary plane shapes, which will independently fill a surface without leaving any gaps. Each shape has its own archetypal behaviour in terms of its self and, in different ways with its own matrix. Hexagons with their 'sixness' and six-sidedness can give rise to smaller or larger patterns by surrounding each point and with a smaller similar figure so that each has a common edge with its neighbour; this implies an indefinitely small and large growth system. The triangle also has many ways of reflecting itself and reproducing itself in a similar manner. It also creates further triangles by forming a link between opposite points of a pair, so that a pattern of six triangles in hexagonal form has two such larger triangles within it.





58 Plywood connection plates set out for cutting with jigsaw, showing all hole positioning for accurate drilling and to facilitate precise positioning and fastening of component members. 42 Large plates and 80 smaller for Y junctions cut and pre-drilled and painted. Four 2400 x 1200 plywood 8mm thick.



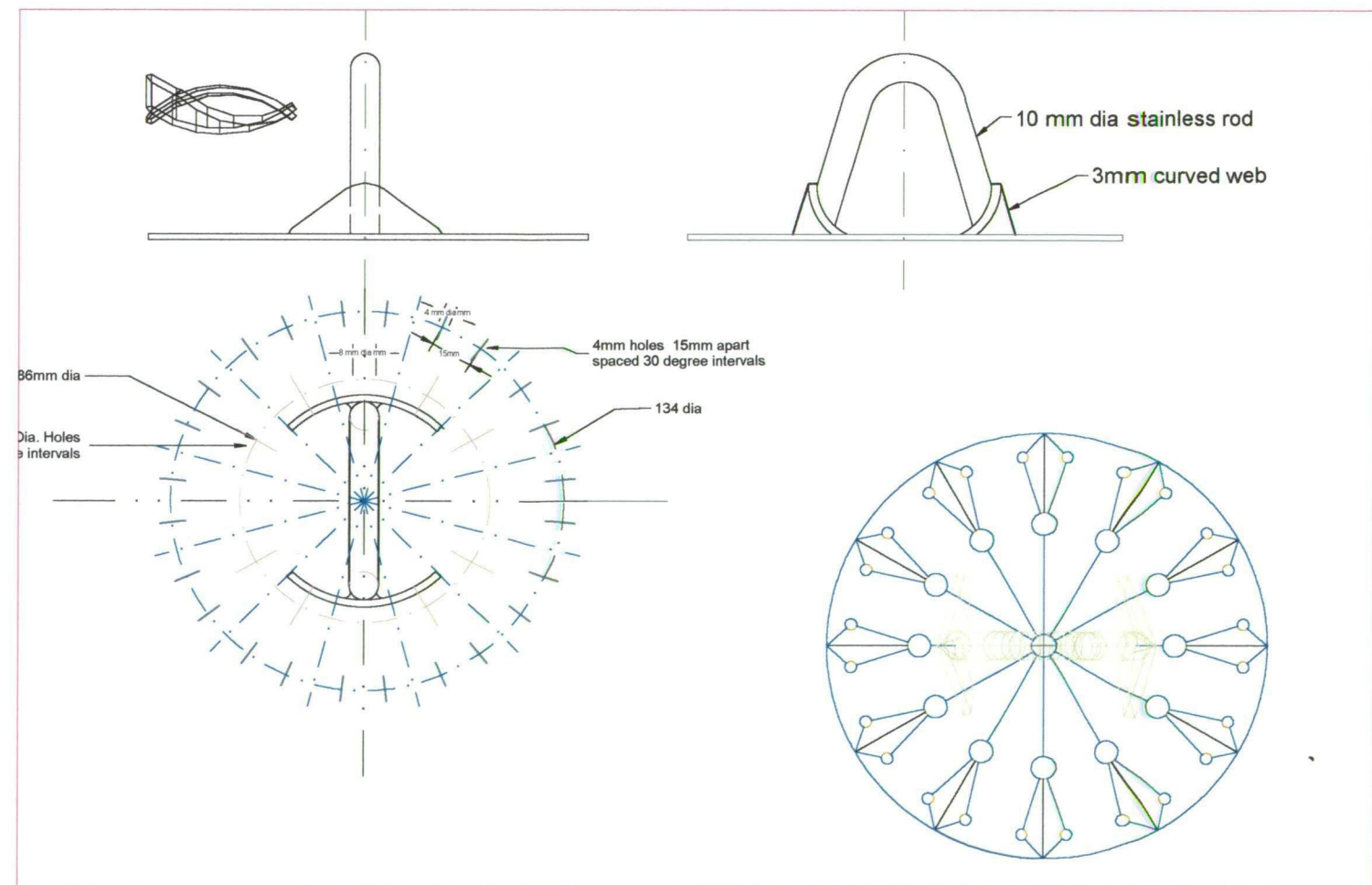
60 Wire frame diagram of Stainless steel lift plate for suspension cable



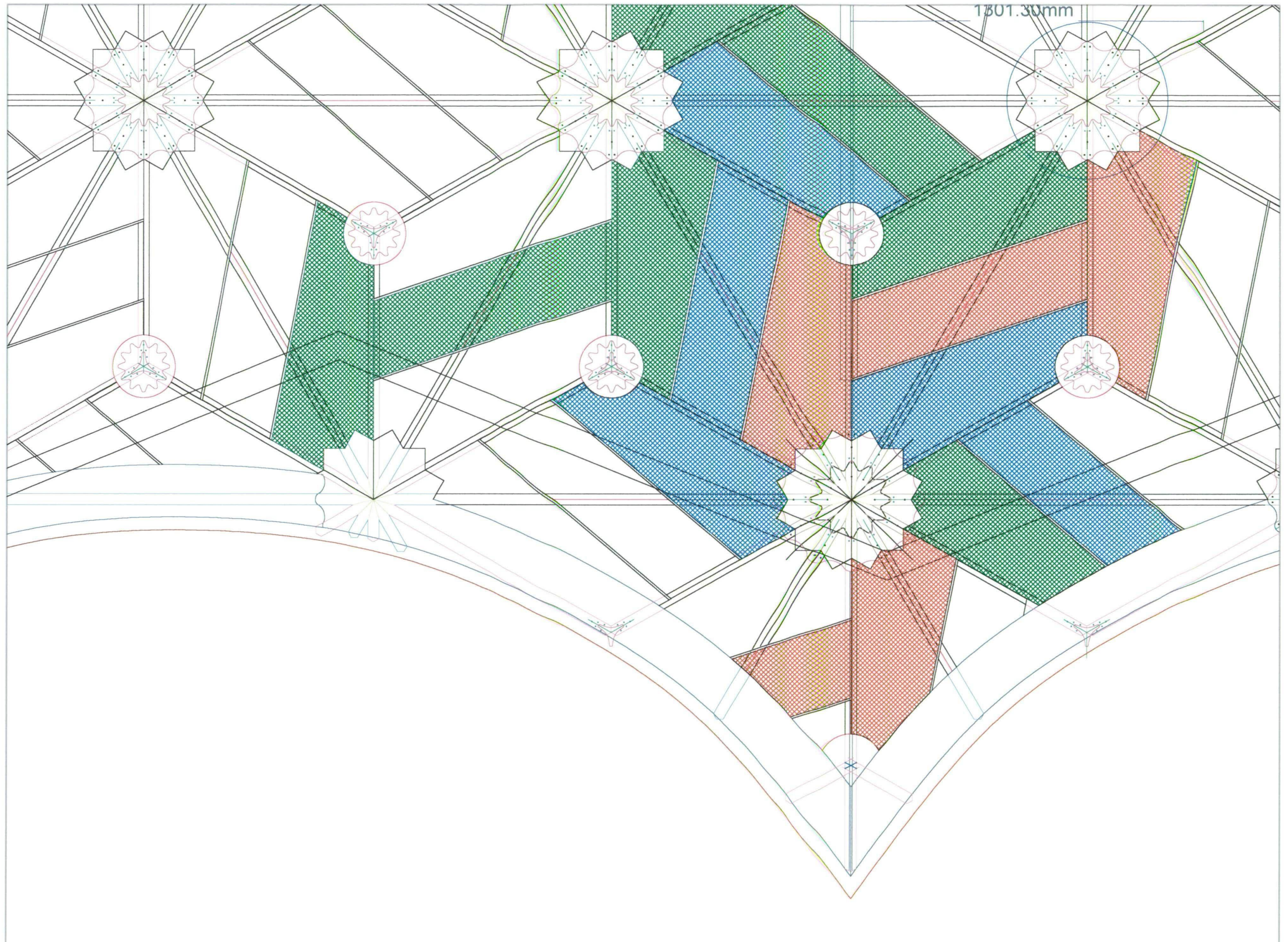
59 3D render view of plate



62 Stainless steel star plate support



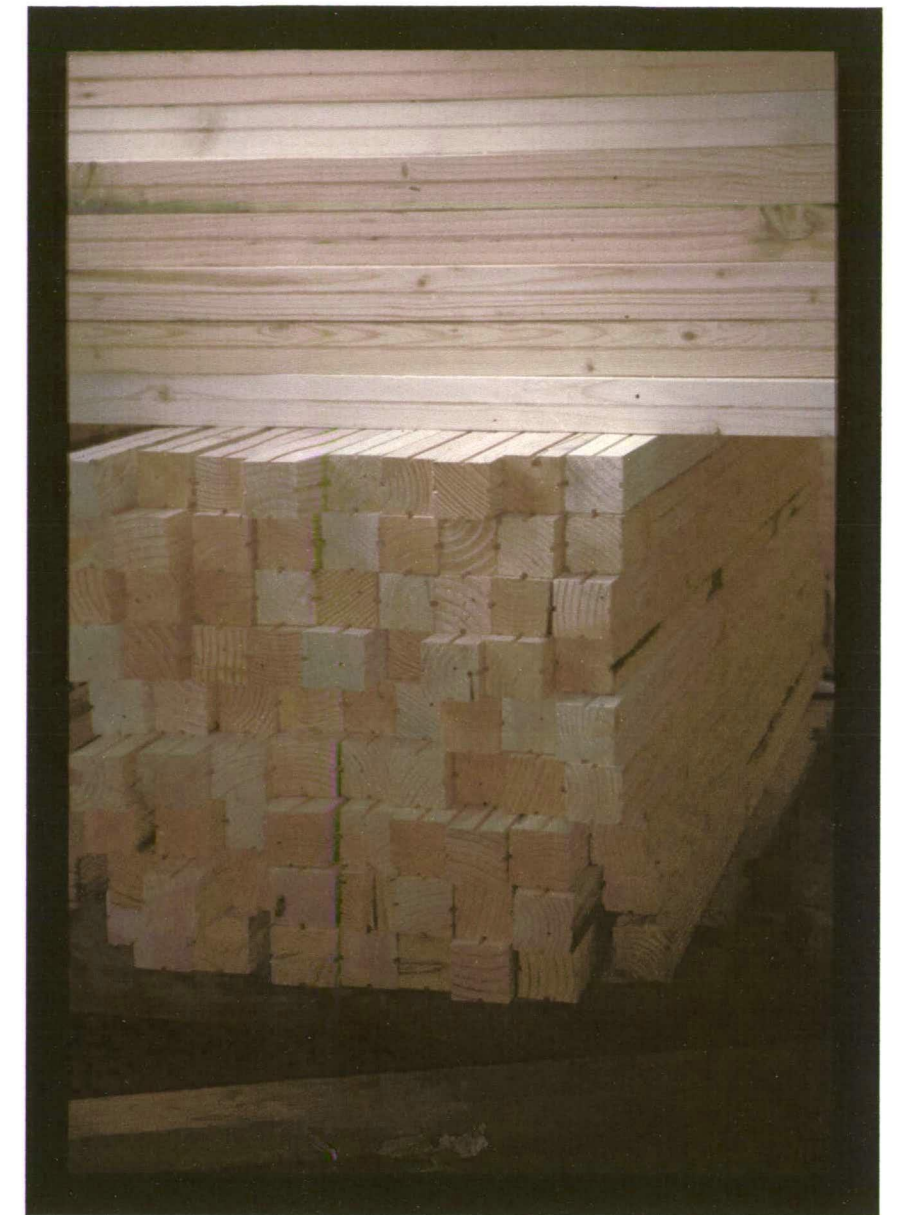
61 Engineering drawing of lift plate



63 Layout of ceiling tile system on roof components



64 Self at the drill press working suspension holes



67 Stack of billets



65 Large stack with Y ends cut and drilled



66 Stack with points cut and sawn centre line

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ILLUSTRATIONS

All line drawings have been printed directly from Turbocad Professional V8 from two dimensional templates, drawings, construction plan engineering drawings, and three-dimensional modelled drawings.

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